SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF EARTH SCIENCE **EARTH SCIENCE**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Earth Observing System	754,500	631,100	663,200	SAT 3-8
Earth Observing System Data Information System	210,100	261,700	231,500	SAT 3-29
Earth Probes	34,900	109,700	138,200	SAT 3-34
Applied research and data analysis	373,400	400,600	420,200	SAT 3-40
Global observations to benefit the environment	5,000	5,000	5,000	SAT 3-62
Launch services	39,400	4,200	---	SAT 3-64
Construction of facilities	---	1,500	1,000	SAT 3-65
Total	1,417,300	1,413,800	1,459,100	
Distribution of Program Amount by Installation				
Johnson Space Center	400	---	---	
Kennedy Space Center	100,620	92,700	66,900	
Marshall Space Flight Center	25,882	18,600	38,300	
Stennis Space Center	37,793	40,400	32,700	
Ames Research Center	8,560	10,200	13,300	
Dryden Flight Research Center	21,456	16,900	19,000	
Langley Research Center	39,876	34,900	59,900	
Glenn Research Center	7,414	---	---	
Goddard Space Flight Center	930,000	928,300	916,000	
Jet Propulsion Laboratory	219,337	222,100	251,700	
Headquarters	25,962	49,700	61,300	
Total	1,417,300	1,413,800	1,459,100	

EARTH SCIENCE ENTERPRISE

PROGRAM GOALS

The purpose of NASA's Earth Science Enterprise (ESE) is to understand the total Earth system and the effects of natural and human-induced changes on the global environment. Earth science is pioneering the new interdisciplinary field of research called Earth system science, born of the recognition that the Earth's land surface, oceans, atmosphere, ice sheets and *biota* are both dynamic and highly interactive. It is an area of research with immense benefits to the nation, yielding new knowledge and tools for weather forecasting, agriculture, water resource management, urban and land use planning, and other areas of economic and environmental importance. In concert with other agencies and the global research community, Earth science is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development. Earth science has established three broad goals. They are to 1) expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft and *in situ* platforms; 2) disseminate information about the Earth system; and 3) enable productive use of Earth science program science and technology in the public and private sectors. The Earth Science Enterprise has evolved from what was previously called the Mission to Planet Earth Enterprise.

STRATEGY FOR ACHIEVING GOALS

The pursuit of Earth system science would be impractical without the continuous, global observations provided by satellite-borne instruments. Earth science comprises an integrated slate of spacecraft and *in situ* measurement capabilities; data and information management systems to acquire, process, archive and distribute global data sets; and research and analysis projects to convert data into new knowledge of the Earth system. Numerous users in academia, industry, federal, state and local government tap this knowledge to produce products and services essential to achieving sustainable development. Earth science is NASA's contribution to the U. S. Global Change Research Program (USGCRP), an interagency effort to understand the processes and patterns of global change.

The Earth Observing System (EOS), the centerpiece of Earth science, is a program of multiple spacecraft (the AM, PM, Chemistry, Landsat-7, and follow-on and supporting technology) and interdisciplinary science investigations to provide a data set of key parameters needed to understand global climate change. The first EOS satellite launches will begin in 1999. Preceding the EOS were a number of individual satellite and Shuttle-based missions which are helping to reveal basic processes. The Upper Atmosphere Research Satellite (UARS), launched in 1991, collects data on atmospheric chemistry. The Total Ozone Mapping Spectrometer (TOMS) instruments, launched in 1978, 1991, and 1996, measure ozone distribution and depletion. Two TOMS instruments were launched in 1996, one on the Japanese Advanced Earth Observing System (ADEOS) mission and the other on a dedicated U. S. Earth Probe. France and the U. S. collaborated on the Ocean Topography Experiment (TOPEX/Poseidon), launched in 1992, to study ocean topography and circulation. The NASA Scatterometer (NSCAT) mapped ocean winds for one year prior to an

on-orbit failure of the Japanese ADEOS-I. In 1997, the Tropical Rainfall Measuring Mission (TRMM) was launched to provide the first-ever measurements of tropical precipitation.

Complementing EOS, under the Earth Probes Program, will be a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and to use innovative measurement techniques in support of EOS. The first two ESSP missions, Vegetation Canopy LIDAR (VCL) and Gravity Recovery and Climate Experiment (GRACE) are scheduled for launch in 2000 and 2001, respectively. The next ESSP missions were selected in December 1998. NASA has chosen for development one primary and two alternate small spacecraft missions. The Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – *Climatologie Etendue des Nuages et des Aerosols* (PICASSO-CENA) mission, co-led by NASA's Langley Research Center and the *Institut Pierre Simon Laplace*, Paris, France will be the next ESSP mission scheduled for launch in 2003. In addition, NASA has chosen two additional missions, CloudSat and the Volcanic Ash Mission (VOLCAM), for further study at the present time. Based on the study results, NASA may select one of these missions for full development and the other as the alternate mission.

Continuing with the recommendation from the 1997 Earth Science Biennial Review, a process is currently under way to define concepts for science and applications missions in the post-2002 time frame. In developing its measurement/mission strategy, the Earth Science Enterprise desires to reduce the risk to overall program objectives from any single mission failure by developing smaller, less expensive missions and implementing shorter development cycles from mission definition to launch. The objectives are to further develop the scientific measurement strategy implemented in the first series of EOS satellite missions and to take advantage of the latest instrument technologies. Shorter development times will allow more flexible responses to current and evolving scientific priorities and more effective uses of the latest technologies. In accordance with this philosophy, the implementation of each future mission in the Earth Science Enterprise (ESE) flight program will be based on a competitive selection of instrument payloads and implementation options. It is important, under this new approach, that instrument technology developments be conducted largely before the relevant mission payload selection. A science and applications-based flight mission profile is indispensable to guide these pre-mission technology developments.

We have obtained a first round of ideas from the science and applications communities for post-2002 mission concepts and are using them to build a nominal multi-mission profile for Earth observation satellite missions in the 2003-2010 time frame.

The purposes of the multi-mission profile are:

- To guide science and application research investments in preparation of the missions;
- To guide ESE technology investment in preparation of the missions; and
- To constitute the basis for discussion with potential commercial and international partners having missions in that time frame for potential cost sharing, collaboration, and partnerships.

The ESE intends to refresh periodically this nominal mission profile through similar consultations with the Earth system science and applications communities. We do not intend to create a 10-year queue of missions, but to promote a theme or focused area at a time leading to selection of one or two missions in each cycle.

Data from Earth science missions, both current and future, will be captured, processed into useful information, and broadly distributed by the EOS Data Information System (EOSDIS). EOSDIS will ensure that data from these diverse missions remain available in active archives for use by current and future scientists. Since these data are expected to find uses well beyond the Earth science research community, EOSDIS will ultimately be accessible by environmental decision-makers, resource managers, commercial firms, social scientists and the general academic community, educators, state and local government—anyone who wants the information.

Following the recommendation of the National Research Council, NASA is exploring the creation of a federation of Earth science information partners in academia, industry and government to broaden the participation in the creation and distribution of EOSDIS information products. As a federation pilot project, 24 organizations were competitively selected in December 1997 to become Earth Science Information Partners (ESIPs) to develop innovative science and applications products.

The intellectual capital behind Earth science missions, and the key to generating new knowledge from them, is vested in an active program of research and analysis. Over 1,500 scientific research tasks from nearly every U. S. state are funded by the Earth science research and analysis program. Scientists from seventeen other nations, funded by their own countries and collaborating with U. S. researchers, are also part of the Earth science program. These researchers develop Earth system models from Earth science data, conduct laboratory and field experiments, run aircraft campaigns, develop new instruments, and thus expand the frontier of our understanding of our planet. ESE-funded scientists are recognized as world leaders in their fields, as exemplified by the award of the 1995 Nobel Prize in chemistry to the two scientists who investigated the threat of cholorflorocarbons to upper atmospheric ozone. The research and analysis program is also the basis for generation of application pilot programs that enable universities, commercial firms, and state and local governments to turn scientific understanding into economically valuable products and services.

The first Earth Science Research Plan was published in 1996. The plan laid out a strategy for study in five Earth system science areas of maturing scientific understanding and significant societal importance: land-cover and land use changes; short-term climate events, natural hazards research and applications; long-term climate change research; and atmospheric ozone research. The plan also outlines some twenty related areas of research which round out the Earth science contribution to Earth system science.

The challenges of Earth System Science, sustainable development, and mitigation of risks to people, property and the environment from natural disasters, require collaborative efforts among a broad range of national and international partners. As mentioned above, the USGCRP coordinates research among ten U. S. government agencies. NASA is by far the largest partner in the USGCRP, providing the bulk of USGCRP's space-based observational needs. NASA has extensive collaboration with the National Oceanic and Atmospheric Administration (NOAA) on short-term climate event prediction. The ESE is the responsible managing agent in NASA for the development of NOAA's operational environmental satellites. NOAA, NASA, and the Department of Defense (DoD) jointly work to achieve the convergence of civilian and military weather satellite systems. NASA collaborates with the U. S. Geological Survey (USGS) on a range of land surface, solid Earth and hydrology research projects. NASA, NOAA and USGS collaborate in the Landsat-7 program, and NASA, DoD and USGS are working together on a third flight of the Shuttle Radar Laboratory modified to yield a digital terrain map of most of the Earth's surface. NASA participates in the World Climate Research Program, the International Geosphere/Biosphere Program, and the ozone assessments of the World Meteorological Organization.

International cooperation is an essential element in the Earth science program. Earth science addresses global issues and requires international involvement in its implementation and application. Acquiring and analyzing the information necessary to address the science questions is a bigger task than a single nation can undertake. Furthermore, the acceptance and use of the scientific knowledge in policy and resource management decisions around the world require the engagement of the international scientific community. Global data and global participation are needed to devise a global response to environmental change. In addition, integrating our complementary science programs can result in fiscal benefits to the NASA program. For this reason, NASA has sought and nurtured international partnerships spanning science, data and information systems, and flight missions. Most of Earth science's satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch services. In the past three years over 60 international agreements have been concluded and more than 40 more are pending. In some capacity, Earth science programs involve international partners from over 35 nations, including Argentina, Armenia, Australia, Belgium, Brazil, Canada, Chile, China, Denmark, Egypt, France, Germany, India, Israel, Italy, Japan, Mongolia, Russia, South Africa, Ukraine and others.

This budget enables the ESE to continue its mission to understand the total Earth system and the effects of natural and human-induced changes on the global environment. While our mission, goals and objectives remain unchanged, our implementation approach continues to evolve. We remain guided by key over-arching Earth science questions while we refine the contributing, lower level questions in response to recent science results. We are using these science questions to drive our technology investment decisions. We have begun the process of identifying post-2002 mission concepts based on how much a given concept contributes to answering a specific science question.

This budget reflects a direct relationship between our strategic plan goals and the resources necessary to implement them. All elements of the budget are tied to our 11 strategic plan objectives. Each performance target in our section of the NASA Performance Plan for FY 1999 and for FY 2000 is traceable to one or more budget elements.

Our first priority is to ensure the success of the Landsat-7 and AM-1-1 missions and that a viable data management system is in place to support the data flow from these missions. We must also sustain support for our other flagship EOS PM, Chemistry, Ice, Cloud, and land Elevation Satellite (ICESat) missions, and sustain Earth Science System Pathfinders (ESSPs) at a viable level.

In addition to ensuring a robust science program, this budget initiates a vigorous Advanced Technology program that supports development of key technologies to enable our future science missions. In addition to our baseline technology program that includes NMP, Instrument Incubator and HPCC, an Advanced Technology Initiative will identify and invest in critical instrument, spacecraft and information system technologies.

The ESE will lead the way in the development of highly capable, remote and *in situ* instruments and the information system technologies needed to support coupled Earth system models. Together they will enable affordable investigation and broad understanding of the global Earth system. The ESE will emphasize the development of information system architectures to increase the number of users of Enterprise information from hundreds to tens of thousands, with the goal of providing easy access to global information for science, education and applications. Finally, ESE will work in partnership with industry and operational organizations to develop the capabilities and infrastructure to facilitate the transition of sustained measurements and information dissemination to commercial enterprises.

ESE's technology strategy seeks to leverage the entire range of technology development programs offering benefits in cost, performance and timeliness of future Earth science process and monitoring campaigns. ESE's strategy is to establish strong links to other government programs in order to maximize mutual benefit to use open competitions for ESE-sponsored technology programs to attract the best ideas and capabilities from the broad technology community, including industry and academia.

Technology efforts will be made in the following areas:

- Advanced instrument and measurement technologies for new and/or lower cost scientific investigations.

- Cutting-edge technologies, processes, techniques and engineering capabilities that reduce development and operations costs and that support rapid implementation of productive, economical, and timely missions;

- Advanced end-to-end mission information system technologies, technologies effecting the data flow originating at the instrument detector through data archival, for collecting and disseminating information about the Earth system and enabling the productive use of Enterprise science and technology in the public and private sectors.

From FY 2000 on, ESE increases emphasis on a viable Applications, Commercial and Education program that bridges our focused research R&A and mission science investments with the Commercial Remote Sensing Program towards addressing key environmental problems of societal relevance.

The EOS AM-1 will be launched in 1999. This mission will provide key measurements that will significantly contribute to our understanding of the total Earth system. The AM-1 instrument complement will obtain information about the physical and radiative properties of clouds, air-land and air-sea exchanges of energy, carbon, and water, measurements of trace gases, and volcanology.

Landsat-7 is also scheduled for launch in 1999. Landsat-7 will carry a single instrument, the Enhanced Thematic Mapper Plus (ETM+), which will make high spatial resolution measurements of land surface and surrounding coastal regions. This mission will provide data continuity with previous Landsat measurements. Landsat data is used for global change research, regional environmental change studies, and other civil and commercial purposes.

With the EOS main missions, such as AM-1 and Landsat-7 that will be launched in 1999, NASA will begin to turn flight data into information. In addition to the EOSDIS that will produce data products for a wide range of users, NASA is engaging in a variety of activities to extend the utility of Earth Science data to a broader range of users such as regional Earth science applications centers, Earth science information partners, and efforts are under way to fuse science data, socio-economic data and other data sets that can be "geo-referenced" in readily understandable data visualizations.

The first of two cooperative missions with the Russian Space Agency (RSA), the Meteor-3M(1) Stratospheric Gas and Aerosol Experiment (SAGE III) mission, is planned for launch in 1999. This mission will collect global profiles of key gaseous species from the troposphere to the mesosphere. The science team will investigate spatial and temporal variability and investigate the effects of aerosols and clouds on the Earth's environment. The Russian METEOR-3M(2) spacecraft is planned to carry the last planned TOMS into orbit in 2000, providing continuity in the essential measurement of the total column of ozone in the stratosphere. However, due to Russian indications that they cannot meet this launch date, NASA is exploring other options.

Five commercial data purchase contracts were awarded in 1998 through the Commercial Remote Sensing Program. Data products will be developed and delivered over the next two years.

The QuikScat spacecraft is ready for launch and is awaiting a launch opportunity. The planned launch in December 1998 was delayed pending the results of the investigation into the failure of a USAF Titan IV launch vehicle earlier in 1998 and related issues with the Titan II. QuikScat, carrying instruments to collect sea surface wind data, will fill the gap in such critical data between ADEOS 1, which failed in June 1997 after seven months on-orbit, and ADEOS II. The availability of components of the Seawinds instrument originally planned for launch on Japan's ADEOS II was accelerated to fly on QuikScat. At present, QuikScat is scheduled for launch in late April 1999. Japan has yet to decide on the timing and form of an ADEOS II mission (or missions), but Earth Science still intends to fly a Seawinds instrument in that context as the follow-on instrument to QuikScat. This will enable continuity of the ocean winds data. In parallel to this development effort, a data buy solicitation for ocean and wind vector data was completed.

Other planned Earth science launches include the Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSat) and the Hyperspectral EO-1 mission in 1999.

The measurements to be made by these and other future Earth science missions as well as current on-orbit missions provide data products that are used extensively in the Earth science program. These activities are providing an ever increasing scientific understanding of global environment and the effects of natural and human sources of change.

BASIS OF FY 2000 FUNDING REQUIREMENT

EARTH OBSERVING SYSTEM

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
AM-1	71,200	31,800	6,200
PM-1	175,900	114,600	119,400
Chemistry-1	110,400	130,400	124,700
Special spacecraft	96,700	116,200	150,000
QuikScat	37,900	10,800	1,100
Landsat-7	74,300	17,000	2,900
Algorithm development	92,300	115,600	127,400
Technology infusion	91,900	90,200	77,600
(New millennium program)	(81,700)	(57,300)	(41,100)
(Sensor & detector/ Technology Initiatives)	(5,500)	(5,500)	(8,900)
(Instrument incubator)	(4,700)	(20,900)	(20,000)
(Advanced Information System Technology)		(6,500)	(7,600)
EOS Follow-on	3,900	4,500	53,900
Total	754,500	631,100	663,200

PROGRAM GOALS

The overall goal of the Earth Observing System (EOS) is to advance the understanding of the entire Earth system on a global scale by improving our knowledge of the components of the system, the interactions between them, and how the Earth system is changing. The EOS data will be used to study the atmosphere, oceans, cryosphere, biosphere, land surface and solid Earth, particularly as their interrelationships are manifested in the flow of energy and in the cycling of water and other chemicals through the Earth system.

The EOS program mission goals are to:

(1) Create an integrated, scientific observing system emphasizing climate change that will enable multi-disciplinary study of the Earth's critical, life-enabling, interrelated processes.
(2) Develop a comprehensive data information system, including a data retrieval and processing system.
(3) Serve the needs of scientists performing an integrated multi-disciplinary study of planet Earth and to make Earth science data and information publicly available.
(4) Acquire and assemble a global database for remote sensing measurements from space over a decade or more to enable definitive and conclusive studies of Earth system attributes.

STRATEGY FOR ACHIEVING GOALS

The EOS contributes directly to accomplishing the goal of understanding global climate by providing a combination of observations made by scientific instruments, which will be integrated with the EOS spacecraft, and the data received, archived, processed, and distributed by the EOSDIS. The selection of scientific priorities and data products responds directly to the USGCRP global change science priorities and the assessment by the Intergovernmental Panel on Climate Change of the scientific uncertainty associated with global climate change.

The three main EOS spacecraft that will support observations by the scientific instruments include the morning (AM), afternoon (PM), and Chemistry. Beginning in 1999, 2000, and 2002 respectively, the satellites will be flown for a period of six years. Additional observations will be provided by the Landsat-7 mission and will begin in 1999.

Nearly all key EOS missions include international contributions. For example, the AM-1 spacecraft will fly an instrument from Canada (Measurements of Pollution of the Troposphere (MOPITT)) and one from Japan (Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)); PM-1 will include the Japanese Advanced Microwave Scanner Radiation (AMSR) instrument and the Humidity Sounder for Brazil (HSB). In addition, numerous agreements have been signed for joint data exchange and distribution, including cooperation in EOSDIS.

EOS program planning began in 1983 with the definition of the science and mission requirements by the EOS Science and Mission Requirements Working Group (SMRWG). The SMRWG charter was to examine the major Earth science questions for the 1990's and to define the requirements for low-Earth-orbit observations needed to answer these questions on a comprehensive multi-disciplinary basis.

The SMRWG's report, issued in 1984, listed five basic recommendations concerning Earth science in the 1990's:

- A program must be initiated to ensure that the present time series of Earth science data are maintained and continued. Collection of new data sets should be initiated.
- A data system that provides easy, integrated, and complete access to past, present, and future data must be developed as soon as possible.
- A long-term research effort must be sustained to study and understand these time series of Earth observations.
- The EOS program should establish an information system to carry out those aspects of the recommendations that go beyond existing and planned activities.
- The scientific direction of EOS should be established and continued through an International Scientific Steering Committee.

The Earth System Sciences Advisory Committee (ESSAC) was appointed in November 1983 by the NASA Advisory Council to consider directions for NASA's Earth science program. The committee's report, issued in May 1986, recognized EOS as the centerpiece of the future Earth science implementation strategy. It stated the following goal of Earth system science: "To obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales." It also identified the following challenge to Earth system science: "To develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activity."

The successor to the SMRWG, the EOS Science Steering Committee (SSC), continued the definition of the EOS program and provided an overall implementation strategy in its report issued in 1987. Concurrent with the SSC work, NASA included the EOS program under a broader Agency initiative termed Mission to Planet Earth, which included other efforts such as the Earth Probe missions and NASA's participation in the International Geosphere Biosphere Program (IGBP) and the World Climate Research Program (WCRP). By proceeding to carry out the recommendations of the SMRWG and the ESSAC, including EOS, the SSC argued that it would be possible to move from a single-discipline research mission to a comprehensive mission addressing all aspects of the Earth as a system. Thus, the concept of an Earth system was adopted as the EOS scientific thrust.

An Announcement of Opportunity (AO) to solicit proposals for EOS investigations was issued in January 1988. The EOS program objectives were based on the requirements and goals of the SMRWG, SSC, and ESSAC. In responding to the AO, the proposers could offer to do interdisciplinary studies that carry out integrated Earth system research leading to the development of comprehensive Earth system models. They could be members of research facility teams (formed to provide scientific guidance for the development of the research Facility Instruments (FIs) and to analyze and interpret data from them). Or they could be Principal Investigators (PI) of proposed instruments and data products. The EOS selection process was completed in February 1989, with the selection of six team leaders and 93 team members for the six NASA research FIs, 24 instrument PIs, and 29 interdisciplinary team PI leaders to participate in the definition phase of the EOS program.

The EOS Investigators Working Group (IWG), formed in 1989, consists of instrument and interdisciplinary PIs and team leaders to provide scientific advice and guidance for the program. The program scientist (from NASA Headquarters) and the senior project scientist (from GSFC) co-chair the IWG. The working bodies of the IWG include twelve science panels. The chairpersons of each of these panels, together with the program scientist and senior project scientist, constitute the Science Executive Committee (SEC) of the IWG. Membership on the panels is generally open to all EOS investigators, including co-investigators on any EOS investigation and members of EOS FI teams. Scientists outside the group of EOS investigators are also included in the various panels.

The IWG plays a leading role in defining the overall science thrust for the EOS program. It coordinates the research efforts and provides guidance and advice to the EOS program and project, as appropriate, concerning all major scientific issues. It will meet regularly throughout the lifetime of the program.

The EOS study project was established at GSFC in 1983. During the Phase A and B study periods, GSFC and the Jet Propulsion Laboratory (JPL) performed mission, data system and spacecraft studies resulting in a conceptual design of a dual series of spacecraft missions that would satisfy the EOS requirements. The spacecraft were designated EOS-A and EOS-B, with GSFC and

JPL having the respective managerial responsibilities. Following the EOS Non-Advocacy Review (NAR), held in June 1989, management responsibilities for the EOS-B series, as well as the project management role for the execution phase of EOS, were transitioned to GSFC. The Synthetic Aperture Radar (SAR), which was a flight instrument to be launched on EOS-B, was identified as an independent mission, to be managed by JPL, and a candidate for separate program approval. In 1990, responsibility for development of the platform was transferred from the space station program to EOS. EOS management became centralized within the EOS project at GSFC.

Congress approved the EOS program as an FY 1991 budget initiative. The payload for the first flight (EOS-A1) was selected in January 1991, following conceptual design and cost reviews of the selected instruments and IWG Payload Panel recommendations on scientific priorities and synergism. The baseline flight segment consisted of two series of large observatories, EOS-A and-B, in 1:30 PM ascending, sun-synchronous orbit, launched by a Titan-IV with solid rocket motor upgrades from the Western Space and Missile Center (WSMC). Each observatory had a five-year life and each was to be replaced twice to provide a 15-year mission. The budget runout through FY 2000 was $17 billion.

The National Research Council (NRC) advises the federal government through reports of reviews it conducts using its various committees, which involve the broad community of science and technology experts. Prior to the EOS new start approval in FY 1991, their report, "The U. S. Global Change Research Program: An Assessment of FY 1991 Plans," provided a critical review of the EOS program.

In the July 1991, report, "Assessment of Satellite Earth Observation Programs 1991," the NRC was in general agreement with the EOS plan for the large EOS-A observatory and its selected payloads. It expressed concern that the total EOS budget size could lead to potential delays, noted data gaps in key areas, and endorsed the Earth Probe concept. These reviews were the beginning of a series of evaluations of the program to ensure the proper scientific return on the EOS investment.

As part of the FY 1992 budget process, the Committees on Appropriations directed NASA to restructure the EOS program to:

- Focus the science objectives of EOS on the most important problem of global change (i.e., global climate change).
- Increase the resilience and flexibility of EOS by flying the instruments on multiple, smaller platforms rather than a series of large platforms.
- Reduce the cost of EOS through FY 2000 to $11 billion.

In the summer and fall of 1991, NASA conducted a restructuring of the program to meet the congressional mandate. This process included an independent review by the External Engineering Review Committee, which issued its report in September 1991. The process also involved assessment by the scientists who will use the data from EOS, including both the EOS IWG and the EOS Payload Advisory Panel. The EOS project at GSFC conducted studies to determine how the EOS instruments could most effectively be configured on small spacecraft. In December 1991, the NASA Administrator reviewed and approved the restructured EOS program, and in March 1992, NASA submitted its report on the restructured program to Congress. Congress approved the restructured program in 1992.

Recognizing that the subsequent budget environment would not support the complete and timely implementation of the restructured EOS program described in the March 1992, report to Congress, the NASA Administrator directed that the program be rescoped with a goal of further reducing its costs through FY 2000 by 30% to $8 billion. The EOS rescope was completed in June 1992, satisfying the 30% reduction by capitalizing on efficiencies, reducing at-launch science data products, by rephasing work, by increasing international participation, and by deleting the High-Resolution Imaging Spectrometer (HIRIS) flight instrument. As a result of the rescoping process, EOS became recognized by NASA as a cost-driven program.

In the 1995 congressional budget cycle, the EOS budget was reduced by $758.5 million through FY 2000, to $7,243.4 million, of which $131.3 million was due to a funding responsibility transfer.

The EOS rebaselining effort conducted in 1994, with the following results, was reflected in the FY 1996 budget submission:

- Preserve the scientific integrity of EOS and Earth science
- Preserve the measurement complement of the first mission in each series
- Preserve the launch dates for AM-1, PM-1 and Chemistry-1
- Phase EOSDIS development to support missions through FY 2000
- Restore reserves to a prudent level
- Incorporate appropriate technology advancements
- Fit within annual funding guidelines for the EOS program
- Replace major spacecraft at six year intervals

Public Law 102-555 returned the development, operations and data distribution of the Landsat-7 project to the federal government in 1992. It established the Landsat Program Management (LPM) team comprised of the DoD and NASA. DoD was responsible for the acquisition of the satellite and NASA was responsible for the development of the ground system. In the fall of 1993, DoD withdrew from the project. At the direction of the National Science and Technology Council (NSTC), the Office of Science and Technology (OSTP) initiated a review and restructuring of the Landsat-7 project. Under Presidential Decision Directive (PDD)/NSTC-3, the Land Remote Sensing Strategy was established. This strategy implemented a project management structure for the Landsat-7 project, which made NASA responsible for development of the satellite, instrument and ground system, NOAA responsible for operations, and the USGS, in conjunction with the EOSDIS Land Process Distributed Active Archive Center (LPDAAC), responsible for data archive and distribution.

During the EOS rebaselining process, the Landsat-7 project was integrated with EOS. As another aspect of the rebaselining, the EOS science project was reorganized. The funding to support the activities of the EOS instrument investigators and interdisciplinary science investigators was moved to research and analysis. The science algorithm development and maintenance remains in the EOS budget.

During 1995, NASA conducted a comprehensive review of EOS to accomplish a number of interrelated objectives: to substantially reduce EOS life-cycle costs while preserving the basic measurement set; to provide for technology infusion that will be available in

time to lower the cost of the follow-on series, to provide new science opportunities through small satellites, and to adjust program management to an evolutionary approach.

This "reshaping" exercise recognized that the first series already employs or advances the state-of-the-art in spacecraft and instruments. Even so, savings achieved in the EOS Data Information System (EOSDIS) implementation and other changes enable some savings and improvements in the first series. These include accelerating Laser Altimetry and Active Cavity Radiometer Irradiance Monitor (ACRIM), by one year, providing a spacecraft for SOLSTICE (previously awaiting a flight of opportunity), and the explicit provision of funding within the EOS budget for new technology missions.

The 1997 Biennial Review completed the shift in planning for future missions (i.e., beyond the EOS first series) that began in the 1995 "reshaping" exercise. Emerging science questions drive measurement requirements, which drive technology investments in advance of instrument selection and mission design. Mission design includes such options as purchase of science data from commercial systems and partnerships with other Federal agencies and international agencies. The result is a more flexible and less expensive approach to acquiring Earth science data.

In the spring of 1998, a Request for Information (RFI) on EOS future missions was released to the broad Earth science community. The RFI responses are being evaluated and will form the basis for redefined future EOS mission profiles with greater detail and higher fidelity cost estimates. After further study and discussion, these mission profiles will be used to focus EOS Announcements of Opportunities (AOs), the first of which is expected for release in 2000.

AM-1

A new generation of Earth science will begin with the launch and checkout in 1999 of EOS AM-1 - one that studies the Earth as a global system. Because the AM-1 spacecraft primarily observes terrestrial features, a morning equatorial crossing time is preferred to minimize cloud cover over land. EOS AM-1 will carry a complement of five synergistic instruments. The Clouds and Earth's Radiant Energy System (CERES) instrument will perform measurements of the Earth's "radiation budget" or the process by which the Earth's climate system maintains a balance between the energy that reaches the Earth from the sun, and the energy that radiates from Earth back into space. The components of the Earth system that are important to the radiation budget are the planet's surface, atmosphere, and clouds. The Multi-angle Imaging Spectroradiometer (MISR) will measure the variation of the surface and cloud properties with the view angle. Meanwhile, the Moderate-Resolution Imaging Spectroradiometer (MODIS) will measure atmosphere, land, and ocean temperature, and moisture profiles, snow cover and ocean currents. The Canadian Measurements of Pollution of the Troposphere (MOPITT) instrument is an infrared gas-correlation radiometer that will take global measurements of carbon monoxide and methane in the troposphere. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), provided by Japan, will measure cloud properties, vegetation index, surface mineralogy, soil properties, surface temperature and obtain digital elevation modes. The primary contractors associated with the project are Lockheed Martin Missiles and Space (LMMS) for the AM-1 spacecraft, Raytheon Sensors and Electronic Systems for the MODIS instrument, TRW for the CERES instrument (the instrument has also been flown on the TRMM in 1997 and will fly on the PM spacecraft), and Lockheed Martin Commercial Launch Services for the AM-1 Atlas Centaur/IIAS launch service.

PM-1

The research focus of the PM-1 spacecraft is atmospheric temperatures and humidity profiles, clouds, precipitation, and radiative balance; terrestrial snow and sea ice; sea-surface temperature and ocean productivity; soil moisture; and the improvement of numerical weather prediction. With the emphasis of the instrument complement being cloud formation, precipitation, and radiative properties, an afternoon equatorial crossing is more suitable for acquiring the data. The primary contractors associated with the project are TRW for the common spacecraft to be used for PM-1; Lockheed Martin Infrared and Imaging Systems (LMIRIS) and JPL for the Advanced Infrared Sounder (AIRS) instrument; and Aerojet for the Advanced Microwave Sounding Unit (AMSU) instrument. Japan will provide the AMSR instrument for the PM-1 spacecraft and Brazil will provide a microwave instrument, the HSB. The launch of PM-1 is scheduled for December 2000.

Chemistry

The Chemistry-1 mission focuses on the impact of greenhouse gases on the global climate. The Project is in Phase C/D developments. The Tropospheric Emission Spectrometer (TES) and the Microwave Limb Sounder (MLS), and High Resolution Dynamics Limb Sounder (HIRDLS) have completed their Preliminary Design Reviews (PDR) in 1997 and 1998 and are now reaching a high level of design maturity. The Ozone Measuring Instrument (OMI), an ozone measuring instrument, is contributed by the Netherlands. The OMI has successfully completed its PDR in December 1998. The launch of Chemistry-1 is scheduled for December 2002.

Special Spacecraft

The Special spacecraft will be designed to study atmospheric aerosols, ocean circulation, ice-sheet mass balance, cloud physics, atmospheric radiation properties, and solar irradiance. Ball Aerospace and Technologies Corporation is responsible for developing the Stratospheric Gas and Aerosol Experiment (SAGE III) that is planned to fly on a Russian spacecraft in 1999, if the Russian launch vehicle is ready, and a flight of opportunity planned for an approximate year 2000 to 2001 launch. The SAGE III will take advantage of both solar and lunar occultation to measure aerosol and gaseous constituents of the atmosphere. The Japanese will provide the Advanced Earth Observing System II (ADEOS II) spacecraft for the Seawinds instrument to measure ocean surface wind velocity as a follow-on to the NASA Scatterometer instrument on ADEOS-I and the Seawinds instrument on QuikScat. The Radar Altimetry mission, Jason-1, will be a follow-on to the TOPEX/Poseidon as a cooperative joint mission with the French Space Agency (CNES), with data provided to NOAA for operational purposes. The EOS Laser Altimetry mission was renamed Ice, Clouds and Land Elevation Satellite (ICESat) to denote its primary objectives of measuring ice sheet height and volume for long-term climate variability studies. The EOS ACRIM, will continue the measurement of Total Solar Irradiance (TSI) begun by the ACRIM instruments on the Solar Maximum Mission and UARS. The Total Solar Irradiance Mission (TSIM), is NASA's science contribution (along with launch services) to the joint NASA/Canadian Space Agency SciSat (science satellite) project, and is the follow-on to the EOS ACRIM mission. TSIM has been explicitly designed to meet the science objectives of both NASA and the National Polar-orbiting Operational Environmental Satellite System (NPOESS).

The Earth Science Enterprise is undertaking a study to look at finding efficiencies in the project by studying the feasibility of combining the SAGE III FOO, TSIM and Solstice instruments into a focused solar irradiance/aerosol mission. This approach could allow greater efficiency in accomplishing these investigations through a more integrated effort. This budget provides funding for a generic mission called the Solar Irradiance and Aerosol Mission (SIAM). The composition of the SIAM mission will be determined in FY 1999.

Landsat

The Landsat-7 1998 activities concentrated on recovering from the instrument thermal vacuum test failure in December 1997. By March 1998, the failure was traced to a part in the power supply design, rework and retest of the instrument got under way in March. Rework and re-integration was completed in May and the instrument returned to its test schedule in June. The ETM+ thermal vacuum testing was completed with no anomalies recorded, and was delivered to the spacecraft in September 1998 with a planned launch date of April 1999.

Technology Infusion

The New Millennium Program (NMP) budget reflects a commitment to develop new technology to meet the scientific needs of the next few decades and to reduce future EOS costs through focused technology demonstrations for Earth orbiting missions. Two Headquarters enterprises are coordinating their project plans to do these missions. The Office of Earth Science has joined the Office of Space Science in the New Millennium Program in order to capitalize on common work from core technology development projects and specific spacecraft and instrument studies. The project will identify and demonstrate advanced technologies that reduce cost or improve performance of all aspects of missions for the next century, (i.e., spacecraft, instruments and operations). The project objectives are to spawn “leap ahead” technology by applying the best capabilities available from several sources within the government, private industries and universities. These low-cost, tightly controlled developments, the Earth Observers (EOs), will take more risk in order to demonstrate the needed technology breakthroughs and thus reduce the risk of using that technology in future science missions. Missions will be selected based on their ability to meet the science needs of the future by innovative technology that would also decrease the cost and improve the overall efficiency of space flight missions.

Increased technology work will be pursued in the areas of sensor and detector systems. Emphasis is being placed on developing new capabilities for Earth science sensors and integrated, autonomous, self-calibrating instruments. Studies are being conducted in the areas of differential absorption Light Direction and Ranging (LIDAR) and OH (hydroxyl) radiometer.

The instrument incubator project is expected to reduce the cost and development time of future scientific instruments for Earth science. The instrument incubator project will aggressively pursue emerging technologies and proactively close the technology transfer gaps that exist in the instrument development process. The project will take detectors and other instrument components coming from NASA’s fundamental technology development projects and other sources, and focus on combining them into new instrument systems which are smaller, less costly, less resource intensive, and which can be developed into flight models more quickly for future Earth science missions. This includes the key follow-on instruments for the EOS.

EOS Follow-On

The next generation of EOS missions will provide new technology and space systems to meet the scientific needs for the NASA Earth science projects. Systematic and process measurements will be defined to support the five science theme areas. In FY 1999 various EOS Follow-On mission studies will be conducted to further define the candidate missions which are part of the EOS future mission profiles. These studies will help to define the mission parameters needed to focus the AO planned for release in 2000. Trades will be conducted on various approaches to satisfying the measurement requirements defined by the RFI process. The mission studies will also provide a basis for technology needs as an input to technology project planning. New instrument technologies will be tested, validated, and made available to support science proposals for selection of measurements, principal investigators, and instruments for the next EOS missions. All EOS measurements, principal investigators, and instruments will be selected as a result of a broad agency announcement that will include peer review, with the goal of a first planned follow on launch for FY 2004. Launches are expected each year through 2009.

SCHEDULE AND OUTPUTS

Preliminary Design Reviews - Confirms that the proposed project baseline is comprehensive (meets all project level performance requirements), systematic (all subsystem/component allocations are optimally distributed across the system), efficient (all components relate to a parent requirement), and represent acceptable risk.

SeaWinds
Plan: May 1995
Actual: May 1995

Meteor-3M Stratospheric Aerosol & Gas Experiment (SAGE III)
Plan: July 1995
Actual: July 1995

Earth Observer-1
Plan: February 1997
Actual: February 1997

PM-1
Plan: April 1997
Actual: April 1997

Jason
Plan: June 1997
Actual: June 1997

ACRIM
Plan: March 1998
Actual: March 1998

ICESat
Plan: June 1998
Actual: June 1998

Earth Observer-2 Revised schedule due to delays in initiating the selection process
Plan: June 1998
Actual: October 1998

Chemistry-1 Rescheduled following completion of alternative configuration studies.
Plan: March 1998
Revised: October 1999

SOLSTICE
Plan: June 1999

TSIM Selection of two teams and refinement of schedule
Plan: March 1999
Revised: January 1999

Critical Design Reviews - Confirms that the project system, subsystem, and component designs, derived from the preliminary design, is of sufficient detail to allow for orderly hardware and software manufacturing, integration and testing, and represents acceptable risk. Successful completion of the critical design review freezes the design prior to actual development.

Earth Observer-1 Schedule changed to accommodate a grating spectrometer, which was recently added to the mission
Plan: April 1997
Actual: June 1997

ACRIM:
Plan: January 1998
Actual: January 1998

PM-1 Plan: April 1998 Revised: June 1998	Revised schedule due to late start following resolution of protest first reported in the 1998 budget
Jason: Plan: November 1998 Actual: November 1998	
Earth Observer-2 Plan: January 1999 Revised: April 1999	Revised schedule due to delays in initiating selection process
TSIM Plan: March 2000 Revised: July 1999	Selection of two teams and refinement of schedule.
Solstice Plan: June 1999	
Chemistry Plan: June 1999 Revised: August 2000	Rescheduled following completion of alternative configuration studies.

Instruments Delivered - Confirms that the fabrication, integration, certification, and testing of all system hardware and software conforms with their requirements and is ready for recurring operation. Throughout system development, testing procedures or, as appropriate, engineering analysis have been employed at every level of system synthesis in order to assure that the fabricated system components will meet their requirements.

Landsat-7 Plan: December 1996 Revised: September 1998	Delays due to technical problems (power supply, panchromatic band noise, mirror scan) and inefficiencies at Raytheon
AM-1 last instrument Plan: February 1997 Actual: August 1997	Test anomalies occurred on the MOPITT instrument; which required rework by Canadians.

SAGE-III (Russian) Plan: December 1997 Actual: September 1998	Due to instrument and detector testing problems.
Seawinds Plan: March 1998 Revised: March 1999	Delayed due to launch slip by Japan.
Earth Observer-1 Plan: October 1998 Revised: May 1999	Schedule changed to accommodate the hyperion alternative for providing the hyperspectral capability following failure to provide functioning detectors
PM-1 last instrument Plan: December 1998 Revised: September 1999	Instrument deliveries delayed, first reported in the 1998 budget
Earth Observer-2 Plan: August 2000	
ICESat Plan: October 2000	
Chemistry-1 last instrument Plan: June 2001 Revised: January 2002	Rescheduled following completion of alternative configuration studies.
QuikScat Plan: May 1998 Actual: May 1998	
ACRIM Plan: October 1998 Revised: June 1999	Instrument delivery changed to fit new launch schedule after selection of launch vehicle and spacecraft vendors.
Jason-1 Plan: March 1999	
TSIM Plan: March 2001	

Algorithm Development (Version 2) - Confirms that the second version of the science software necessary for the production of the standard data products for each mission has been developed and is ready to support launch.

AM-1
Plan: February 1998
Actual: February 1998

Aerosol SAGE-III (Russian) Commensurate with the delay in instrument delivery.
Plan: December 1997
Revised: June 1999

SeaWinds
Plan: September 1998
Actual: September 1998

Jason-1 Revised due to delayed selection of science team and revised launch date.
Plan: December 1998
Revised: October 1999

Earth Observer-1
Plan: April 1999

PM-1
Plan: July 2000

Chemistry-1
Plan: December 2001

ICESat Revised due to delay selection of science team.
Plan: July 2002
Revised: January 2001

Launch Readiness Dates - Verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

AM-1 Plan: June 1998 Revised: July 1999	Significant delays in the EOSDIS Flight Operations System (FOS) have resulted in the delay of the EOS AM-1 launch.
QuikScat Plan: November 1998 Revised: April 1999	Delayed due to USAF Titan IV failure investigations and launch site availability conflicts.
Landsat-7 Plan: Dece3mber 1998 Revised: April 1999	Delays due to technical problems (power supply, panchromatic band noise, mirror scan) and inefficiencies at Raytheon
ACRIM Plan: October 1999 Revised: November 1999	Availability of launch vehicle
Aerosol SAGE-III (Russian) Plan: December 1998 Revised: September 1999	Revised to increase mission reliability by enhancing the testing of critical subsystems for the newly developed METEOR spacecraft and Russian funding delays.
Earth Observer-1 Plan: 1998 Revised: December 1999	Schedule changed to accommodate the Hyperion alternative for providing the hyperspectral capability following failure to provide functioning detectors
Seawinds (ADEOS-II) Plan: August 1999 Revised: November 2000	Delayed due to launch slip by Japan.
Jason 1 Plan: December 1999 Revised: May 2000	Delayed to accommodate spacecraft development by French Space Agency (CNES) partner
PM-1 Plan: December 2000	
Earth Observer-2 Plan: January 2001	

Chemistry-1
Plan: December 2002

ICESat Due to new catalog spacecraft approach, the launch was originally accelerated by six months.
Plan: July 2002
Revised: January 2002

TSIM
Plan: December 2001

SOLSTICE
Plan: December 2002

ACCOMPLISHMENTS AND PLANS

AM-1

Integration and test of the integrated AM-1 spacecraft was completed in the first quarter FY 1998. Version 1 of the science software was delivered in the second quarter of FY 1998. The second external independent readiness review was held prior to the start of environmental testing of AM-1 (with all instruments integrated onto the spacecraft). Environmental testing was completed in the second quarter of FY 1998. In 1999, the spacecraft will be delivered to the Astrotech commercial launch processing facility at the Vandenberg AFB, California, where system end-to-end testing will be performed and preparation for launch will be completed. Launch is scheduled for no earlier than July 1999.

PM Spacecraft

The PM-1 spacecraft design phase was completed and a successful Critical Design Review was held in June 1998. Fabrication and assembly of the spacecraft is well under way, with a scheduled completion date of June 1999. Integration and test of PM-1 is scheduled to begin in June 1999. Several instruments have completed final assembly and environmental testing. The remainder are scheduled for completion in the Spring of 1999. Instrument delivery to PM-1 is planned for completion in September 1999. The common spacecraft CDR was completed in FY 1998. The common spacecraft will complete fabrication and begin integration and test in 1999.

The integration and test of the EOS PM-1 spacecraft will be completed in FY 2000. Science software deliveries will be completed and ground system and operations preparations will be completed. PM-1 remains on schedule to meet a launch readiness date of December 2000.

Chemistry Spacecraft

The Chemistry mission, focusing on the impact of greenhouse gases on global climate has been maturing in terms of instruments design concepts. The HIRDLS, MLS, and TES have initiated Phase C/D development. HIRDLS, MLS, and TES successfully completed PDRs in 1997 and 1998. These instruments are in a detailed design and development phase. Negotiations are under way with the Netherlands for them to provide an OMI. The Chemistry project is in Phase C/D. The OMI being a late addition to the instrument suite for the Chemistry platform is beginning its design and development effort and successfully PDR in late 1998. In 1999 MLS, TES, HIRDLS, and OMI CDRs will be completed, including the engineering models for each. HIRDLS will be in the fabrication phase. A draft version of the science Algorithms Theoretical Basis Document (ATDB) will be completed for TES and MLS and HIRDLS.

The common spacecraft delta CDR specific to the Chemistry Mission is planned for 2000. Ground system operational requirements will also be completed. Each of the Chemistry Instruments will be completing Engineering Model testing and calibration activities, and will begin conducting Flight Model Integration and Test activities during 2000. The MLS and TES Instrument Teams will be delivering Beta Versions of their Science Data Processing (SDP) software during 2000. All of the Instrument Teams will be developing the L-24 Engineering Versions of their SDP software. Fabrication, Assembly and Test of Common Bus subsystems that are also common to the PM spacecraft will be completed during 2000. The Common Spacecraft CDR specific to the Chemistry Mission is also planned for 2000. Ground system operational requirements will also be completed.

Special Spacecraft

The Jason-1 MOU between NASA and CNES was signed in December 1996.. CNES will provide the spacecraft, solid-state altimeter, and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) positioning system. NASA will provide the microwave radiometer, global positioning system and laser retroreflector array. The ground system and mission operations will be shared. NASA will also provide the launch services. Delays in the CNES satellite development program and altimeter development have caused the reschedule the launch of Jason-1 to May 2000. NASA supported a Jason-1 PDR in June 1997 and initiated the Boeing Delta II launch vehicle contract in September 1997. NASA instrument progress was ahead of schedule, with the Jason Microwave Radiometer engineering model component delivered.

The Jason-1 activities for 1998 focused on the completion of the critical design for all flight elements. Engineering model development and test is complete for the technologically difficult instruments, the altimeter and microwave radiometer. The CDRs for these instruments were both held early in 1998 to support a system-level CDR for the satellite in June 1998. Flight models of the instruments were built during the second half of 1998 for delivery to the payload integration activity at CNES next year. Another critical activity under way in 1998 was the design and development of the Dual Payload Attach Fitting (DPAF) an addition to the launch vehicle structure that would accommodate the dual Jason-1/TIMED payload on the Delta II launch vehicle.

CNES held the system-level CDR for the Jason-1 mission with NASA support in the fall of 1998. Simulators or engineering models of all the instruments will be delivered to CNES, who will perform platform and payload integration and test as separate activities. The flight models of all the instruments will be delivered by mid-1999 and the test readiness review for the ground system will be held in June 1999. Satellite-level integration and test is scheduled to being by mid-summer 1999. CNES will ship the integrated satellite for Jason-1 to the Western test range and launch is scheduled for May 2000 on the Delta launch vehicle, co-manifested with NASA's TIMED space science satellite. After launch and a 60-day checkout, normal mission operations are scheduled to being, including formation flying with the TOPEX/Poseidon satellite, to provide cross correlation for scientific trend analysis of the sea-surface height.

The ICESat team selected Ball Aerospace and Technologies Corporation's spacecraft contractor from the Goddard Space Flight Center's catalog of industry standard spacecraft in February 1998. The GeoScience Laser Altimeter System (GLAS) PDR was held in June 1998 and followed by a successful confirmation review by an independent team of the overall mission. The ICESat activities for 1999 will focus on flight hardware fabrication. The mission approach to using the catalog spacecraft allows a streamlined development schedule, so that the traditional PDR, CDR sequence was modified to a single Mission Design Review which is scheduled for early FY 1999. The GLAS engineering model will be tested and delivered to the spacecraft and fabrication of the flight model will begin. The launch vehicle for ICESat will be selected in 1999. The critical activities for ICESat in 2000 will be spacecraft flight hardware environmental testing. The beta version of the ICESat algorithms will be delivered to EOSDIS for testing of the data product generation. Due to using the new catalogue spacecraft approach, the launch has been accelerated six months.

The Solar Stellar Irradiance Comparison Experiment (SOLSTICE) continued to make progress in Phase B towards a December 2002 launch. SOLSTICE successfully completed a conceptual design and cost review in March 1998 and LASP issued a request for proposals for a SOLSTICE spacecraft. In FY 1999 SOLSTICE will complete final design of the three flight instruments and select the spacecraft contractor. The SOLSTICE mission design review, combining PDR and CDR, will be held in June 1999. The key milestone for SOLSTICE in FY 2000 will be the spacecraft design review scheduled for the second quarter.

There are two Stratospheric Gas and Aerosol Experiment (SAGE version III) instruments being manufactured for long-term monitoring of ozone and aerosol. The instrument is in the final phase of test and development. The first SAGE III mission is planned to fly on a Russian Meteor-3M spacecraft in 1999. The instrument was completed in 1998 and will be shipped to Russia in March 1999, as long as the Russian launch vehicle is ready. The second mission is a Flight of Opportunity (FOO), planned for an early turn of the century launch once an affordable opportunity is identified. The logistics, testing, integration, and launch plans are in place with the Russians for the Meteor-3M spacecraft for the first mission. The two SAGE III instruments were delivered in 1998.

The Seawinds CDR was completed in January 1996. The Seawinds instrument continued to undergo protoflight model fabrication and assembly during FY 1998. The Seawinds instrument activities will consist of integration and test of the instrument. The protoflight model is scheduled for delivery to Tsukuba, Japan in March 1999 for a November 2000 launch on the ADEOS II spacecraft by a NASDA H-II rocket from Tanegashima, Japan.

The Active Cavity Radiometer Irradiance Monitor (ACRIM) continued to make excellent progress on instrument fabrication and spacecraft development in 1998, on schedule for a launch in FY 1999. The ACRIM spacecraft was manifested on a Taurus launch vehicle (dual launch with Korean Spacecraft). The ACRIM mission will make final preparations for launch in FY 1999 including integration of the ACRIM payload onto the Orbital spacecraft and installation of the ACRIM ground station at Table Mountain California. ACRIM will hold a Mission Readiness Review in September 1999. In FY 2000 NASA will launch ACRIM (October 99) and begin the five-year mission.

NASA awarded contracts for the Total Solar Irradiance Mission (TSIM) Phase B design studies to two contractors in July 1998: the University of Colorado, Laboratory for Space and Atmospheric Physics and the Naval Research Laboratory. In the first quarter of FY 1999 the two mission teams will present their mission design reviews. Based on the evaluation of the two TSIM designs, the Associate Administrator will select a single contractor in January 1999 to continue developing the TSIM mission. In June 2000 TSIM will hold a CDR on-track for a launch in December 2001.

In an effort to align related science investigations while reducing overall costs, the Office of Earth science is undertaking a study to look at the feasibility of combining the SAGE III FOO, TSIM and Solstice instruments into a focused solar irradiance/aerosol mission. A team has been established to evaluate the probability of this mission with the findings culminating in the second quarter of FY 1999.

QuikScat

The QuikScat mission will fill the ocean-wind vector data gap created by the loss of the NASA Scatterometer (NSCAT) on the Japanese Advanced Earth Observing Satellite (ADEOS-I) spacecraft. The NSCAT instrument ceased to function when ADEOS-I failed in 1997. The follow-on Scatterometer, Seawinds, is scheduled for launch on the Japanese ADEOS-II spacecraft in November 2000. Spares from the Seawinds instrument were used to assemble the QuikScat Scatterometer instrument. Ball Aerospace and Technologies Corporation of Boulder, Colorado was selected in 1997, to provide the QuikScat spacecraft. Ball was selected via the Indefinite Delivery Indefinite Quantity (IDIQ) rapid delivery spacecraft contract. QuikScat will be completed in 1998 and ready for launch, pending launch site availability. The most likely available launch date, using a Titan-II from Vandenberg Air Force Base, is presently April 1999.

Lightning Mapper

During FY 1998 significant progress was made on the Lightning Mapper Sensor (LMS) including design of key electronics. This culminated in a successful Systems Requirements Review. Procurements were awarded for two key subsystems of LMS. The advancements that will be made on the Charged Coupling Device (CCD) and the optics assembly through these procurements will contribute substantially to the risk mitigation of the final instrument.

Landsat

After the original instrument anomalies were corrected, the Landsat-7 ETM+ instrument was delivered again in September 1998. Spacecraft integration and testing continues. Testing was completed in the Fall of 1998. End-to-end test of the spacecraft and ground system will be completed in early FY 1999.

The spacecraft will be delivered to California Space Port commercial launch processing facility at the Vandenberg AFB where systems end-to-end testing will be performed and preparation for launch will be completed. Launch is planned in April 1999.

While the original plans called for the transition of Landsat-7 operations to NOAA after launch, there is now an alternate proposal being considered where NASA would temporarily operate the satellite in preparation for transition of full operational responsibilities to the US Geological Survey (USGS).

Technology Infusion

The New Millennium Program (NMP) focuses on identifying and demonstrating, in flight, advanced technologies that reduce cost or improve performance of spacecraft and instruments. The NMP emphasizes partnering with industry, academia and other Government agencies.

The Earth Observer (EO-1) Advanced Land Imager is the first mission selected under the NMP series and is scheduled for launch in 1999. The EO-1 consists of an Advanced Land Imager (ALI) instrument, a spacecraft, and numerous advanced technologies as an integral part of the mission. The EO-1 is in Phase C/D and has completed CDR.

Due to the manufacturing difficulties at the ALI detector contractor, the hyperspectral imaging capability of the ALI was descoped to multispectral imaging only to preserve the overall mission schedule and cost. The decision was made in the summer of 1998 to continue the hyperspectral capability, however, through another contractor's design. This capability will augment the ALI but will not impact the existing design. The hyperspectral functionality will be provided by an additional module called Hyperion to be completed by TRW. The Hyperion delta CDR was completed this year. In 1999 the EO-1 mission will be launched.

Following selection, development of the Space-Readiness Coherent Lidar Experiment (Sparcle) was started in May 1998 as EO-2. The Sparcle mission is scheduled for launch in 2001. The mission will fly an infrared laser in the cargo bay of the Space Shuttle to determine if a space-based sensor can accurately measure global winds within Earth's atmosphere from just above the surface to a height of about 10 miles. The measurement in this region of the atmosphere may lead to improved weather forecasting and a better understanding of climate-related events such as El Niño.

The Announcement of Opportunity for the EO-3 mission was released in 1998; mission concept selection is planned in early 1999.

The advanced technology initiatives activities will focus and refine ESE technology requirements, including system trade studies and the development of technology roadmaps. Architectural concepts developed under the advanced concepts element are carried forward to determine the specific system, subsystem and component performance metrics required for their implementation.

This element also advances key component and subsystem technologies required for the next generation of process and monitoring missions. An example is the current sensors and detectors project that includes the development of LIDAR technologies for profiling winds and chemical constituents within the Earth's atmosphere, spectrometers that can return high quality EOS level-2 science products at lower total mission cost and radiometers for passive microwave and millimeter wave remote sensing. These activities are complementary to the Space Science Enterprise-supported Cross-Enterprise Technology Development Program (CETDP), NASA's primary advanced technology program developing component and subsystem technologies at early stages of maturity. While CETDP has the charter for generic technologies with value to multiple NASA enterprises, ESE's advanced technology initiatives element is focused on technologies specific to ESE needs.

For 1998 the advanced technology initiatives element include the development of LIDAR technologies for profiling winds and chemical constituents within the Earth's atmosphere, spectrometers that can return high quality EOS level-2 science products at lower total mission cost and radiometers for passive microwave and millimeter wave remote sensing.

Also under this element, systems trade studies were conducted in 1998 in the following areas:

- Visible/Near-IR Remote Sensing Options
- High Data-Rate Instrument Requirements
- Systems Issues on Formation and Constellation Flying
- LIDAR Studies
- Molniya Earth Orbit (MEO) Applications-Science/Cost Benefits
- Geostationary orbit (GEO) Missions
- Advanced Microwave Radiometry
- GPS Surface Reflection Technology for Space
- Tropospheric Measurement Options

The Instrument Incubator Project (IIP) supports the development of new instruments and measurement techniques from paper studies through laboratory development and ground or air validation. NASA Research Announcements (NRAs) are used as the vehicle to search the combined public and private science/technology community for the best new ideas and development capability. NASA received 123 proposals of which 27 have been selected and are planned to be on contract by February 1999. Selected projects include three from industry, six from NASA field centers, eight from universities and ten from national laboratories. Areas for instrument development within the project include land-cover and land-use change and global productivity research; seasonal-to-interannual climate variability and prediction; natural hazards research and applications; and long-term climate observations -- natural variability and change research, and atmospheric ozone research.

The advanced geostationary study effort has been evaluating various new imaging, sounding, and lightning mapper instrument concept designs and technologies that could be applied to using geosynchronous orbit as a cost effective vantage point for supporting Earth science research objectives as well as NOAA observational requirements. The study effort has also investigated technologies and concepts for advance geosynchronous spacecraft and associated ground data processing and distribution techniques required to support the advanced instrumentation. All activities have been closely coordinated between NASA and NOAA.

EOS Follow On

In the spring of 1998, a Request for Information (RFI) on EOS future missions was released to the broad Earth science community. The RFI responses were evaluated and form the basis for redefining future EOS mission profiles with greater detail. After further study and discussions, these mission profiles will be used to focus EOS Announcement of Opportunities (AOs), the first of which is expected for release in 2000.

Funds will be used to carry selected instruments through detailed design and engineering model development. In FY 1999, fabrication of CERES flight model number 5 will continue; the instrument provides Earth radiation budget measurements. Other instrument studies will be conducted in FY 2000 in accordance with the Announcements of Opportunities that will be issued.

One study under way is examining the feasibility of developing and deploying an atmospheric temperature and humidity sounding system which meets both the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) and NASA scientific requirements for obtaining atmospheric temperature and moisture profiles. This sounding system will include an infrared sounder and a microwave sounder. The system is anticipated to be flown and operated on the NPOESS-C1 spacecraft and subsequent NPOESS and/or European METOP spacecraft. An initial implementation agreement between NASA and the NPOESS Integrated Program Office was signed in August of 1998.

BASIS OF FY 2000 FUNDING REQUIREMENT

EARTH OBSERVING SYSTEM DATA INFORMATION SYSTEM

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Earth Observing System Data Information System.....	210,100	261,700	231,500

PROGRAM GOALS

The goals for the EOS Data Information System (EOSDIS) are the development and operation of a highly integrated system which can: (1) operate the EOS satellites; (2) acquire instrument data; (3) produce data and information products from the EOS, to preserve these and all other Earth science environmental observations for continuing use; and (4) make all these data and information easily available for use by the research, education, government agencies and all those who can benefit from them in making economic and policy decisions. The EOSDIS facilitates the goals of Earth science by enabling the public to benefit fully from increased understanding and observations of the environment.

STRATEGY FOR ACHIEVING GOALS

The EOSDIS is based on an evolutionary design to develop capabilities with the phased deployment of the EOS satellites and to enable adaptation to changes in user needs and technology. NASA is making extensive use of prototypes to assure that EOSDIS will effectively meet the needs of the satellites and users. A limited amount of technology development and adaptation is focused specifically on meeting EOSDIS evolutionary needs while relying on other projects at NASA and other agencies to fund technology development efforts of a more generic nature, i.e., communications technology. An initial version of the system, Version 0, implemented at eight Distributed Active Archive Centers (DAACs) and through cooperative efforts with NOAA, the USGS, and international partner space agencies, became operational in 1994.

Plans for development of subsequent versions of the EOSDIS have been redrawn. Due to continuing problems and schedule delays with completion of the Science Processing Software System (SPDS) and the Flight Operations System (FOS), two important components of the EOS Core System (ECS), we have focused ECS work on operational support for the near-term missions (AM-1 and PM-1) and with post-launch deliveries of software restoring some of the originally planned capability.

EOSDIS development has been divided into four major components: The EOS Data and Operations System (EDOS) which has been developed by TRW, the EOSDIS Backbone Network (EBNet) which has been developed in-house by GSFC with support contractors, the ECS which is under development by Raytheon, and the DAACs. The EDOS receives the raw data stream from the satellites, separates the data by instruments, and performs the initial processing (packet restoration and temporal ordering) and back-up archiving. The EBNet delivers the real-time data to and from the operations control centers and the science data to the DAACs described below. The ECS includes the FOS, which provides satellite and instrument command and control, and the SDPS, which provides the systems to process the EOS science data and integrate the EOSDIS user functions. The DAACs currently have a limited operational capability using EOSDIS Version 0. The EOSDIS Independent Validation and Verification (IV&V) contract is with Intermetrics Systems Services Corporation.

The EDOS element of EOSDIS has been developed and a flight ready version has been installed and tested. The EDOS systems are ready to support the launch and operations of the AM-1 satellite. The EDOS consists of a TDRSS ground station at White Sands Complex (WSC) and back-up polar ground stations (PGS) in Alaska and Norway. The raw satellite data will be sent from the ground stations to the Level-0 processing center at Goddard Space Flight Center, which will process the data and send it to the DAACs. EOS missions following AM-1 will not use the WSC TDRSS ground stations, but will rely on the PGS.

Using the ECS, the eight DAACs will process the raw data from the satellites into useful science products, handle user product searches, requests, orders, and distribute data and information directly to the user community. The DAACs also archive all Earth science data and information for future use. To better serve the user community, each DAAC focuses on the data needs of a specific segment of the user community. A user-working group (advisory panel) guides each DAAC.

The eight DAACs are:

- Alaska Synthetic Aperture RADAR (SAR) Facility, University of Alaska Geophysical Institute, Fairbanks, Alaska
- Earth Resources Observation System (EROS) Data Center (EDC), U.S. Geological Survey, Sioux Falls, South Dakota
- Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
- Langley Research Center, Hampton, Virginia
- National Snow and Ice Data Center, University of Colorado, Boulder, Colorado
- Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee
- Socio-Economic Data and Applications Center (SEDAC), Lamont-Dougherty Earth Observatory, Columbia University, Palisades, New York

Currently, EOSDIS Version 0 allows direct access to selected pathfinder data holdings from the USGS and NOAA. Relationships with Canada, Japan, Russia, Israel, Australia and several European countries have been established for the exchange of data for EOSDIS. Many multi-agency efforts, in addition to the NASA EOSDIS, are working to improve data availability to the public, especially in the Interagency Working Group on Data Management for Global Change and the Federal Geographic Data Committee.

In response to the recommendations by the NRC Board on Sustainable Development, NASA is currently prototyping a new organizational concept for data product generation and distribution. NASA has selected institutions to form a working prototype environmental information federation. The federation will develop concepts for data set interoperability and collective management of a data system, comprised of dispersed, nominally independent data centers.

In light of difficulties in development of the SDPS, NASA has also begun moving responsibility for processing some of the critical EOS Standard Data Products to the EOS Instrument Teams (ITs). The teams have proposed to process the EOS data at their institutions leveraging their NASA provided Science Computing Facilities.

SCHEDULE AND OUTPUTS

EOSDIS Version 1 Plan: January 1997 Revised: Replaced	Provide support for science data processing, archival, and management of the data from the two EOS instruments operating on the TRMM spacecraft. The ECS contractor failed initial test readiness for EOSDIS Version 1 and NASA issued a Stop Work Order. Replacement systems were developed at GSFC and LaRC, (extended "Version 0" in-house system), and the systems are performing successfully.
EOSDIS Version 2 Plan: October 1997 Revised: January 1999 through December 1999	Provide support the launch of AM-1 and Landsat-7. Technical difficulties by the ECS contractor have required a descope in the original requirements planned for Version 2. NASA has issued a Request for Proposal to Raytheon for a reduced requirements set (A+). The requirements will be provided in a set of incremental deliveries beginning in January 1999 and ending in December 1999. The first increment provides for support for launch of Landsat-7 and AM-1, while the additional increments provide for increasing user services and processing capacity is under way.
EOSDIS Version 3 Plan: December 1999 Revised: June 2000	Provide science processing and flight operations support for PM-1. Will support flight operations and science processing, but with descoped capability.
EOSDIS Version 4 Plan: December 2000	Provide science processing and flight operations support for CHEM-1. Will support flight operations and science processing, but with descoped capability. Provides final increment of ECS A+ requirements.

Providing broad and efficient access to data products is key to meeting the Agency mission of advancing and communicating scientific knowledge. The successful functioning of EOSDIS is essential to the accomplishment of all three of Earth science's strategic goals. Three key indicators of DAAC performance are the volume of data archived (approximately 180 terabytes at the end of FY 1998), the number of users accessing the DAACs (over 1 million distinct users accessing the DAACs in FY 1998), and the number of data products delivered in response to user requests (approximately 4.5 million data products delivered in FY 1998).

ACCOMPLISHMENTS AND PLANS

The EOSDIS suffered major development delays in 1998 that resulted in the inability to support the on-time launch of the AM-1 spacecraft. The Flight Operations Segment (FOS) development had a significant failure in March 1998 that resulted in slip of over 12 months in critical launch support capability. Since then, performance stability has been achieved in three of the four major subsystems: command management, planning and scheduling and data management. Performance and schedule problems with the command procedure execution software (used for real time command and control of spacecraft) have persisted, and Raytheon has made the decision to replace this segment of the system with a Raytheon-developed spacecraft control system called "Eclipse".

Raytheon's development of the EOSDIS Core System (ECS) Science Data Processing System (SDPS) also continued to have critical schedule delays and cost overruns. The delays in SDPS are attributable to two key factors: 1) ambitious requirements and the overall complexity in the design of the system, and 2) the high rate of turnover in information technologist personnel (Raytheon has experienced an annual turnover greater than 30% since contract start). The current schedule for achieving all planned capabilities for AM-1 and Landsat-7 is now three years later than the contract date, and this assumes that the development staff is maintained at current levels instead of declining in FY 1999 as planned under the baseline schedule. Due to budget overruns, the requirements for the SDPS have been significantly descoped and system capabilities were prioritized and partitioned into incremental software deliveries. The first delivery of critical software needed to support AM-1 launch was delivered to the DAACs in July 1998 and testing of the code is under way. Since June, numerous deliveries of "patches" have been delivered to fix problems discovered in testing. NASA has formulated a plan that will ensure delivery of the remaining essential ECS capability needed to support AM-1 data processing and AM-1 and Landsat-7 archiving, while containing further cost overruns. This plan includes the potential transition of responsibility for some higher-level data products to the Instrument Teams where appropriate. NASA also began planning a strategy for future implementations of the enterprise data information systems and services. A team comprising NASA managers and science and data system experts was selected to perform a study establishing a roadmap for future data system development.

Other elements of EOSDIS needed to support the AM-1 mission continued on schedule and within budget. The EOS Data and Operations System (EDOS) was delivered and is undergoing acceptance testing, including end-to-end tests with the spacecraft, to support command uplink and data acquisition. The GSFC and LaRC DAACs have successfully supported science processing and data management for the CERES and LIS instruments on TRMM since the TRMM launch in November 1997.

The Environmental Information Federation experiment was officially begun in 1998 with the selection of 24 Working Prototype Earth Science Information Partners (WP-ESIPs) early in the year. The WP-ESIPs held their first organizational meeting in May 1998 and have begun working on issues of collective management and data set interoperability. The 24 WP-ESIPs in the Federation experiment represent the broad science and applications community and include representatives from educational, industry, regional governments and consortium, and NASA data centers. Implementation of the federation is being carried out in parallel with the development of EOSDIS and the Distributed Active Archive Centers (DAACs).

A key focus in 1998 was a review of the eight DAACs by the National Research Council. The NRC reviewers visited each DAAC and assessed its effectiveness through interviews with DAAC customers. NRC is currently finalizing their report on the DAAC peer review.

In FY 1999, EOSDIS will finish development of the FOS using the Eclipse software to support the launch of AM-1 in the third quarter of 1999. The EOSDIS will have several key system deliveries in 1999. The ECS FOS needed for launch support of the AM-1 spacecraft (using the eclipse software) will be delivered and tested in time to support a launch of AM-1 no earlier than May 1999. The SDPS delivery needed to support launch will complete end-to-end testing at the DAACs in January 1999. A second delivery of the software to provide automated support as data flows reach operational levels, to prepare for Y2K, and to support remaining external data sources and higher level products will occur in June 1999. During 1999, selected Instrument Teams (MODIS and MOPITT) will complete the development of their Science Investigator Processing Systems (SIPS) to process some of the higher level EOS standard data products. EOSDIS will begin processing, archiving and distributing data from Landsat-7 and AM-1. By the end of the year, the DAAC archive volume, user accesses, and product deliveries should all be increasing significantly.

The Federation Experiment and the Working Prototype Earth Science Information Partners will be in full swing in 1999. NASA will begin evaluating the federated approach as a model for supplying future earth science data information systems and services and the early results from the Federation Experiment will be factored into the ESE data systems and services strategic planning efforts. The strategy team will complete their study and issue an ESE data systems and services implementation plan in late spring.

Another key milestone for 1999 will be the issuance of the NRC report on the peer review of the ESE Distributed Active Archive Centers (DAACs). The NRC Committee on Global Environmental Data will issue their report in January 1999. A NASA management team will evaluate the report and make recommendations regarding DAAC certification to the Associate Administrator for Earth science.

In FY 2000, operations and continued development of the EOSDIS will be the primary tasks. Additional EOSDIS Core System (ECS) software deliveries in FY 2000 will provide additional capabilities to AM-1 and Landsat-7 data users to facilitate search and access to a growing, complex global data base. A key milestone will be the further development of the EOSDIS to support the requirements for the PM-1 and ICESat missions scheduled for delivery in June 2000. Higher level processing of the science data products from PM-1 will be accomplished at the DAACs or by the PM-1 science teams at their institutions as appropriate, while the EOSDIS DAACs will provide data archival, distribution, and user support.

The Federation Experiment will enter its final year in 2000. The WP-ESIPs will be busy completing their science data set productions and achieving smooth operations as a federation. NASA will complete their evaluation of the experiment and decide on the feasibility and strategy for evolving EOSDIS into a federated architecture.

BASIS OF FY 2000 FUNDING REQUIREMENT

EARTH PROBES

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Total Ozone Mapping Spectrometer	6,000	4,900	4,900
Tropical Rainfall Measuring Mission	900	0	0
Earth System Science Pathfinders	22,800	62,200	75,200
Lewis & Clark	1,400	100	0
LightSAR	0	5,000	20,000
Experiments of opportunity	2,900	2,500	1,000
Triana	900	35,000	35,100
University Class Earth System Science	0	0	2,000
Total	34,900	109,700	138,200

PROGRAM GOALS

The Earth Probes program is the component of Earth science that addresses unique, specific, highly-focused mission requirements in Earth science research. The program was designed to have the flexibility to take advantage of unique opportunities presented by international cooperative efforts or technical innovation, and to complement the Earth Observing System by providing the ability to investigate processes that require special orbits or have unique requirements. The currently approved Earth Probes are the Total Ozone Mapping Spectrometer (TOMS), Tropical Rainfall Measuring Mission (TRMM), Triana, Earth System Science Pathfinders (ESSP), and LightSAR. NASA plans to add the University Class Earth System Science (UNESS) pathfinders to the Earth Probes program.

STRATEGY FOR ACHIEVING GOALS

TOMS

The scientific objectives of the TOMS project are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS flights build on the experience that began in 1978 with the launch of a TOMS instrument (flight model 1) on Nimbus-7 and continued with the TOMS instrument (flight model 2) on a Russian Meteor-3, launched in 1991, a TOMS (flight model 3) launched on the Japanese ADEOS in 1996 and the Earth Probe spacecraft also launched in 1996. The remaining development TOMS project consists of one instrument (flight model 5, designated FM-5). The FM-5 has been completed, is in storage, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has indicated that it cannot meet that launch date. Presently, the Agency is in the process of exploring other options.

Earth System Science Pathfinder

The Earth System Science Pathfinder (ESSP) is a science-driven project intended to identify and develop in a short time, small satellite missions to accomplish scientific objectives in response to national and international research priorities not addressed by current projects. ESSP will provide periodic "windows of opportunity" to accommodate new scientific priorities and infuse new scientific participation into the Earth science program. By launching ESSP missions on a regular basis, NASA will provide a mechanism by which pressing questions in Earth system science may be addressed in a timely fashion, permitting a continual improvement in our understanding of the Earth system and the processes that affect it.

The first two ESSP missions and an alternate mission were selected in March 1997. The Vegetation Canopy Lidar (VCL) mission, led by a University of Maryland, College Park Principal Investigator, completed Phase B and has begun its fabrication phase with an expected launch date of February 2000. The second mission, Gravity Recovery and Climate Experiment (GRACE) which is led by a Principal Investigator from the University of Texas at Austin with significant participation by the German Aerospace Center (DLR), is in an extended Phase B with launch expected in June 2001. A minimum amount of funding is being provided to the Chemistry and Circulation Occultation Spectroscopy Mission (CCOSM) to maintain this spacecraft as an alternate to replace VCL or GRACE if significant difficulties develop.

The second ESSP announcement of opportunity was released in the third quarter of FY 1998, with selection in December, 1998. NASA has chosen for development one primary and two alternate small spacecraft missions. The Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – *Climatologie Etendue des Nuages et des Aerosols* (PICASSO-CENA) mission, led by NASA's Langley Research Center will be the next ESSP mission scheduled for launch in 2003. PICASSO-CENA is designed to address the role of clouds and aerosols in the Earth's radiation budget. It will employ innovative light-detection and ranging (LIDAR) instrumentation to profile the vertical distribution of clouds and aerosols, while another instrument will simultaneously image the infrared emission of the atmosphere. During the daylight half of its orbit, PICASSO-CENA will measure the reflected sunlight in an oxygen absorption band and take images of the atmosphere with a wide-field camera. The total estimated mission cost of PICASSO-CENA, including launch vehicle, is $173.5 million, of which NASA will provide $117.4 million. PICASSO-CENA will be launched in 2003. It consists of a partnership between Langley Research Center, France's Centre Nationale D'Etudes Spatiale (CNES), the Institute Pierre Simon LaPlace, Hampton University of Hampton, Virginia (a Historically Black University), the Ball Aerospace and Technology Corporation and the Goddard Space Flight Center. France is providing a PROTEUS spacecraft, the infrared imaging system, and science analysis support.

In addition, NASA has chosen two additional missions, CloudSat and the Volcanic Ash Mission (VOLCAM), for further study at the present time. Based on the study results, designed to mitigate several areas of risk identified during the evaluation, NASA may select one of these missions for full development, and the other as the alternate mission. NASA intends to solicit another set of ESSP missions in the fall of 2000.

Lewis & Clark

The Lewis and Clark missions were intended to be a new way of doing business for NASA with the satellites being developed, launched and delivered on orbit in 24 months or less with minimal government oversight. The two missions were to demonstrate different land imaging capabilities and other measurements of scientific interest to Earth science. The Lewis mission was a medium resolution hyperspectral instrument.

The Lewis spacecraft was built by TRW. Lewis was launched in August 1997. Shortly after launch communications with the spacecraft were lost. Clark was planned to carry 36 new technologies including composite structures, advanced avionics, high-efficiency power systems, and a high resolution multispectral imager. The Clark spacecraft was built by Orbital, formerly CTA Space Systems of Rockville, Maryland, as part of the small spacecraft technology initiative program. In February 1998 after extensive reviews, NASA terminated the Clark Earth science mission due to mission costs, launch schedule delays and concerns over the on-orbit capabilities the mission might provide. NASA has retained the launch vehicle services. Disposition of the Clark assets is currently under review.

LightSAR

The LightSAR project is consistent with direction included in House Report 104-812 which stipulated that NASA's FY 1998 budget include additional funding to accomplish this project. LightSAR is a proposed free-flying, Earth-observing, lightweight, synthetic aperture radar (SAR) mission. It could be used as part of NASA's long-term investment in the development and prosperous use of imaging radar science and technology in the public and private sector. Past spaceborne radar missions have established the vast potential of imaging radar for expanding scientific knowledge of the Earth and planets. LightSAR could demonstrate new technologies that reduce the cost and enhance the performance of SAR missions and could contribute to the next level of expansion for the U. S. commercial remote sensing industry. Industry cost sharing is required before the program can proceed.

Triana

The Triana mission is an Earth observation spacecraft to be located at the Sun-Earth L1 point providing a near-term real time, continuous high definition color view of the full sun-lit disc of the Earth.

During 1998 the mission was studied at GSFC and an Announcement of Opportunity (AO) was released by NASA Headquarters in July soliciting proposals for full Triana mission implementation. A selection was made in November for the Scripps Institution of Oceanography to build and conduct the Triana mission. Triana will carry the Earth Polychromatic Imaging Camera built by Lockheed Martin Advanced Technologiy Company, a radiometer built by the National Institute of Standards and Technology, and a plasma magnetometer that measures solar wind built by GSFC and the Massachusetts Institute of Technology. Launch is scheduled for December 2000.

Experiments Of Opportunity

This project offers a capability to undertake short duration flights of instruments on the Space Shuttle and other platforms. The Earth Science Enterprse has used the capability of Shuttle/Spacelab development in the important areas of design, early test and checkout of remote sensing instruments for free flying missions, and short-term atmospheric and environmental data gathering for scientific analysis. Instrument development activities have supported a wide range of instrumentation, tailored for Space Shuttle and airborne missions.

UNESS

The University Class Earth System Science pathfinder (UNESS) project consists of spaceborne investigations of modest science scope. These investigations will be lead by U.S. university principal investigators with significant student involvement. The Announcement of Opportunity is planned for release in 1999, which is expected to lead to an award of four phase A studies. These studies will result in a selection of two missions for launch in 2001 and 2002.

SCHEDULE AND OUTPUTS

Launch Readiness dates – verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

Vegetation Canopy Lidar
Plan: 1999
Revised: May 2000

The Vegetation Canopy Lidar (VCL), the ESSP mission 1, is scheduled to launch in May 2000. The later launch date reflects the delay in initially selecting and contracting the first ESSP missions.

Triana
Plan: December 2000

PICASSO-CENA
Plan: 2003

Gravity Recovery and Climate Experiment
Plan: June 2001

The Gravity Recovery and Climate Experiment (GRACE) scheduled to launch in 2001.

ACCOMPLISHMENTS AND PLANS

The first ESSP announcement of opportunity was released in FY 1996 and the selection occurred in March 1997. The first two missions are the Vegetation Canopy Lidar (VCL) and the Gravity Recovery and Climate Experiment (GRACE). The Earth Science Enterprise selected three small spacecraft missions as a result of the second ESSP AO. The primary mission is PICASSO-CENA (Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – Climatologie Extendue des Nuages et des Aerosols. This is a joint mission with NASA's Langley Research Center and the Institut Pierre Simon Laplace, Paris, France. The instruments on PICASSO-CENA are designed to address the role of clouds and small atmospheric particles known as aerosols and their impact on Earth's radiation budget. The spacecraft is planned for launch in 2003.

In addition to the PICASSO-CENA mission, NASA has also selected two additional ESSP missions, CloudSat and Volcanic Ash Mission (VOLCAM), as alternate missions. These two missions will proceed through an extended development and technology assessment prior to the decision of which mission will be the primary and alternate. The CloudSat mission is focused on understanding the role of thick clouds in the Earth's radiation budget. This mission will use advanced cloud profiling to provide information on the vertical structure of highly dynamic tropical cloud systems. VOLCAM is a pathfinder mission for demonstrating the operational and scientific applications of monitoring volcanic clouds and aerosols from a geostationary orbit.

The LightSAR project made substantial progress in 1998. JPL, Stennis Space Center, and four independent industry teams completed detailed studies that defined free-flying Earth observing lightweight synthetic aperture radar (SAR) missions that could deliver Earth science data, validate valuable new technologies, and lead the next level of expansion for the U.S. commercial remote sensing industry. The industry studies concluded that LightSAR could establish U.S. leadership in SAR science, technology and commercial remote sensing by providing greater capabilities at significantly lower cost than any existing or planned free-flying SAR systems. The study also concluded that industry is ready to participate and invest in LightSAR and create long-term businesses that become sustained providers of valuable science and commercial remote sensing data. Industry cost sharing is required before the program can proceed.

In preparation for project start, a payload technology alliance was formed in March 1998. Through the alliance, the best available SAR technologies in the public and private sectors are being developed and validated. This alliance also provides for shared funding contributions as well as technology. These activities are providing early risk mitigation of the critical technologies that will enhance the performance and reduce the mass and cost of LightSAR. A draft AO was released on November 25, 1998 for comments. It will be officially released in January 1999. Proposers will have 45 days from the official AO release date to prepare and submit their proposals.

The Experiments of Opportunity Program supported the STS-87 mission, which was launched in November 1997, carried the Shuttle Ozone Limb Sounding Experiment (SOLSE) and the Limb Ozone Retrieval Experiment (LORE) instruments. The SOLSE shuttle flight successfully demonstrated that the task of limb scatterometry could be used for high-vertical resolution ozone profiles in the lower stratosphere.

Experiments of Opportunity Program is the funding source for NASA's participation in the *Satellite de Applicaciones Cientificas-C* (SAC-C) mission. SAC-C is a joint mission between NASA and the Argentine Space Agency (CONAE). The mission is co-manifested with NASA's New Millennium Earth Orbiter-1 mission and is scheduled for late 1999 launch. NASA is providing launch vehicle, scalar helium magnetometer and GPS receivers. Argentines have various instruments such as multispectral scanner, and high resolution camera, etc. The spacecraft and the instruments completed CDR and are in various stages of manufacturing and testing. Spacecraft thermal and structural models were tested and qualified in 1998. The magnetic mapping payload has been calibrated as well. The main focus in 1999 is to finish the fabrication, integration and test of the spacecraft and payloads. The mission will be in operation in the year 2000.

The TOMS flight model 5 has been completed, is in storage, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has delayed this mission until the year 2002 or later due to funding problems. Presently, the Agency is in the process of exploring other options.

BASIS OF FY 2000 FUNDING REQUIREMENT

APPLIED RESEARCH AND DATA ANALYSIS

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Earth Science Program Science	303,800	323,700	337,300
Operations, Data Retrieval, and Storage	69,600	76,900	82,900
Total	373,400	400,600	420,200

PROGRAM GOALS

The goal of applied research and data analysis is to advance our understanding of the global climate environment, the vulnerability of the environment to human and natural forces of change, and the provision of numerical models and other tools necessary for understanding global climate change.

STRATEGY FOR ACHIEVING GOALS

The applied research and data analysis program is divided into two components: Earth science and Earth science operations, data retrieval, and storage. The activities under Earth science program science include research and analysis, EOS science, airborne science and applications, the purchase and management of scientific data, commercial remote sensing and Uncrewed Aerial Vehicle (UAV) science project. Operations, data retrieval and storage consists of several independent activities responsible for the operation of currently functioning spacecraft and flight instruments, high performance computing and communications, and the provision of computing infrastructure. Each of the major components of applied research and data analysis has its own set of goals, strategies for achieving goals, performance measures, and accomplishments and plans.

BASIS OF FY 2000 FUNDING REQUIREMENT

EARTH SCIENCE PROGRAM SCIENCE

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Research and analysis	169,400	171,000	182,100
EOS science	41,400	46,400	60,600
Mission science teams and guest investigators	45,900	48,100	38,800
Airborne science and applications	20,700	18,100	21,400
Uncrewed aerial vehicles (UAV)	1,900	2,000	4,000
Advanced geostationary studies	3,000	---	---
Commercial remote sensing	21,500	38,100	30,400
Total	303,800	323,700	337,300

PROGRAM GOALS

The goal for the Earth science research program is to contribute to the integration of the Earth and environmental sciences into an interdisciplinary scientific understanding of the Earth system and the effects of human-kind on the global environment. Major emphasis is placed on providing early warning and fast response to global environmental changes that pose risks to society. The science program also provides the analysis and integration of critical data and models needed for national and international assessments. An objective of current planning is to achieve the most essential, long-term objectives of EOS and to increase effort on science with near-term payoff, within a sustainable level of funding. The observational program will become resilient, better, and cheaper in the future by (1) taking advantage of the experience being gained in preparation of the first round of EOS flight missions to reduce observing requirements in the future and to simplify the design of instruments for more cost-effective continued operation, (2) finding alternative means to carry out some of the essential measurements at the same level of quality through cooperation with other agencies and nations, and (3) infusing new ideas and technologies into the EOS program through small satellite missions that have lower infrastructure and flight costs.

STRATEGY FOR ACHIEVING GOALS

The Research and Analysis (R&A) science project is essential to the discovery of new concepts and to the design of future missions. The primary mode of research coordination occurs through the USGCRP, the Committee on the Environment and Natural Resources (CENR) Subcommittee on Global Change Research, and the various boards and committees at the National Academy of Science. The Research and Analysis consists of five priority areas: Land Use/Land Cover, Short-term Climate Change, Long-term Climate Change, Natural Hazards, and Atmospheric Ozone.

The Science strategy of interdisciplinary research is to increase scientific understanding of the global environment and its vulnerability to both human and natural factors of change (e.g. pollution, climate variability, deforestation). Viewing the Earth from space is essential to comprehending the cumulative influence of human activities on its natural resource base. An important priority is to provide accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources. Observations from space are the only source of objective information on the human use of land in a time of rapid land use development. A related priority is to improve understanding and prediction of transient climate variation, such as El Niño anomalies. Reducing uncertainties in climate predictions a season or a year in advance would dramatically improve agriculture and energy utilization planning. Natural hazards research is exploring the use of remote sensing observations for mitigation of drought and flood consequences. There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like El Niño events. Special attention is being given to measuring and modeling the effects of relative forces, like clouds, aerosols and greenhouse gases in long-term climate change, in order to improve our assessments of climate trends on time scales of decades to centuries. A continuing priority is to understand the causes and consequences of changes in atmospheric ozone. Emphasis is now being placed on the changing composition of the lower atmosphere, which is sensitive to the unprecedented increase of pollutant emissions in rapidly developing regions throughout the world.

EOS science consists of focused research projects to analyze specific Earth science data sets and interdisciplinary investigations geared for a broader probe into Earth science system functions. The former is needed to control quality of data produced by interdisciplinary instrument computing facilities and the latter for bridging disciplinary boundaries. Both types of efforts are being supplemented by graduate student participation in the EOS science fellowship project.

The objectives of the mission science team/guest investigators are to analyze data sets from operational spacecraft that support global climate change research in atmospheric ozone and trace chemical species, the Earth's radiation budget, aerosols, sea ice, land surface properties, and ocean circulation and biology.

The airborne science project funds operations of two ER-2s and one DC-8 aircraft. The project funds operation and support of a core of remote sensing instruments and a facility for analyzing and calibrating data from those instruments. The specially modified aircraft serve as test beds for newly developed instrumentation and their algorithms prior to spaceflight. The instrumented aircraft provide remote sensing and *in situ* measurements for many Earth science research and analysis field campaigns, including stratospheric ozone, tropospheric chemistry, and ecological studies throughout the world. The ER-2 aircraft, in particular, are unique in that they are the highest flying subsonic civilian research aircraft and were key in collecting *in situ* data for our understanding of ozone depletion and stratospheric transport mechanisms. One of these provided support and observations, including overflights of hurricane *Georges*, for an interagency experiment designed to improve our capability to predict hurricane landfall and intensity. The DC-8 aircraft provides a unique "flying laboratory" facility for a broad range of disciplines in atmospheric sciences.

The Uncrewed Aerial Vehicle (UAV) science project will augment the Earth science airborne project. Initially it will make *in situ* and remote sensing measurements focused on atmospheric sciences. These UAVs will stay over a target for extended periods to measure detailed temporal changes, provide unique views of cloud structures and provide calibration and verification of Earth science satellite instrumentation.

The Commercial Remote Sensing Program (CRSP) funds cooperative efforts with industrial, university, and state and local government partners aimed at enabling development of a viable commercial remote sensing industry. The cooperative effort will work to apply space-based data and instrument technology in the development of usable, customer-defined information products. Industry and others will make significant co-investments, funding or in-kind contributions to the co-developed projects at about an equal level with NASA. NASA and industry will work in a "joint discovery" mode to identify requirements for advance remote sensing observations/measurements, e.g., hyperspectral and SAR data that respond to and help satisfy future commercial market demand.

SCHEDULE AND OUTPUTS

The scientific issues of concern to Earth science are among the most complex and policy relevant of any major scientific research program. The results of Earth science program science are critical to the development of sound U. S. and global environmental policy, necessary for long-term sustainable development. Each of the science theme areas discussed in the accomplishments and plans section describe performance targets to ensure that the goal and objectives of the Earth science program science are met. A summary schedule and outputs relating to management, business practices, and bases for comparisons applicable to the whole Earth science program are in the table below.

	FY 1998 Actual	FY 1999 Estimate	FY 2000 Estimate
Number of principal investigators	1,075	1,100	1,175
Number of research tasks under way	1,500	1,525	1,600
Average duration of research tasks	3 years	3 years	3 years
Number of science solicitations released	19	21	22
Number proposals received	928	975	1,025
Number of proposals rated very good to excellent	498	525	550
Number of proposals selected	343	355	360
Time to process proposal (selection through obligation)	60 days	45 days	30 days
Number of days until funding is released	Simultaneously with award	Same	Same
Percent of R & A funding obligated:			
Current Budget Authority:	81%	87%	100%
Prior Budget Authority:	100%	100%	100%
Percent of program reviewed by science peers	95%	95%	95%

ACCOMPLISHMENTS AND PLANS

Research and analysis and EOS Science

In FY 1998, continuing into FY 1999 and FY 2000, the following are significant accomplishments in the areas of Land Cover/Land Use, Short-Term Climate Events, Long-Term Climate System Variability, Natural Hazards, and Atmospheric Ozone, EOS Science and Applications, and Education and Outreach

Land Cover/Land Use

The ESE will provide some of the underlying science to permit assessments of the current distribution of land-cover and land-use. It will examine the changes that have taken place in the last several decades, their impact on bio-geochemical cycling, biophysical processes, bio-diversity, trace gas and particulate fluxes, and coastal zone conditions. In addition, the likely impacts of future land-cover change will be assessed.

In FY 1998, NASA led an interagency effort to establish a web-site for Fire Monitoring by Satellite at http://modarch.gsfc.nasa.gov/fire_atlas/fires.html. Fire is one of the major disturbances of ecological systems around the world. Satellite observations of fire occurrence provide a systematic means of establishing baseline data and monitoring changes in fire occurrence and extent.

Satellite data analyses were published which showed a time-lag in the response of terrestrial ecosystems to climate variability. The response of ecosystems to climate variability influences the degree to which the biosphere is a net source or sink of carbon. The existence of time lags in the response is a critical feature of understanding how land-cover and land-use change might affect atmospheric composition.

The ESE produced a historical data set of key climate variables for the U. S. for the last 100 years and produced climate scenario data for the next 100 years for use in model inter-comparison studies and the U. S. National Assessment on the Potential Consequences of Climate Variability and Change. These historical data sets have a wide variety of uses in ecosystem modeling. The future climate scenarios provide the raw material for understanding what the potential climate impacts in the U. S. might be.

On December 10, 1998, the NASA Administrator and the President of the Central American Commission on the Environment and Development (CCAD) signed a Memorandum of Understanding (MOU) establishing cooperation between CCAD and NASA in support of the Mesoamerican Biological Corridor. The membership of CCAD consists of the Governments of Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama; and all have agreed to work together within the CCAD framework to promote the sustainable development of the entire Central American region. In 1997 the Presidents of the seven Central American countries specifically endorsed the concept of a Mesoamerican Biological Corridor, running throughout the Central American isthmus, with a goal of integrating conservation and the sustainable use of the region's biodiversity.

Under the terms of the MOU, NASA (including the Marshall Space Flight Center, Jet Propulsion Laboratory, and other NASA-funded investigators) and Central American researchers will use satellite data to develop maps classifying the land cover of the Central American isthmus according to: life zones, land-use types, geological structure, hydrology, and other factors. NASA will also support the development of CCAD's environmental data and information system by making available optical, radar, and topographic remote-sensing data to CCAD. The MOU will initiate a new partnership between NASA and the countries of Central America and demonstrate the utility of NASA Earth science data and information for both biodiversity conservation and the planning of sustainable development.

The first year of near-daily global ocean color data from SeaWiFS was completed in September 1998. Weekly maps of surface-ocean chlorophyll distributions reveal dynamic seasonal patterns in primary production during the 1997-98 El Niño. The time series will be used to understand and predict the response of marine ecosystems to environmental change.

In FY 1998, ecological and biogeochemical cycling research on the effects of tropical forest conversion were initiated under the Brazil-led Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA). Remote sensing studies in collaboration with the Brazilian National Institute for Space Research have documented the amounts and rates of deforestation in the 1990's and will continue with LBA. Mosaics of JERS-1 satellite radar images for the entire Amazon region have been produced in collaboration with Japan for both the peak wet and dry seasons, allowing an analysis of seasonally inundated forest areas. Field observations in Brazil and other Amazonian countries of carbon stores and fluxes, trace gas fluxes, nutrients in soils and vegetation, and land use practices and impacts will begin in 1999 and continue through 2002.

In FY 1999, we will begin to refresh the global archive of 30-meter land imagery from Landsat 7, three to four times per year. From the instruments on the EOS AM-1 spacecraft, and through the EOSDIS, we will begin collecting near-daily global measurements of the terrestrial biosphere. This is an index of terrestrial photosynthetic processes from which calculations of carbon uptake are made. In addition, we will collect near-daily global measurements of ocean color. This will provide an index of ocean productivity from which calculations of ocean update of carbon are made.

In FY 2000, NASA contributions to the First National Assessment of the Potential Consequences of Climate Variability and Change will be completed. These will include production of the climate scenario information, support of the National Synthesis, several of the U. S. regional analyses, and supporting research for several U. S. studies. We will participate in the Southern Regional Science Initiative-2000 (SAFARI-2000) regional international assessment in South Africa. This assessment will quantify the effects of climate variability and management practices on the environment.

Near-real time fire monitoring and impact assessment based on Landsat and EOS inventory and process monitoring will provide an observational foundation for monitoring changes in ecosystem productivity and disturbance. The ocean color time series with 60% global ocean coverage every four days will continue.

Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) will merge MODIS ocean color data into the global ocean color time series that began with Ocean Color Temperature Sensor (OCTS) and SeaWifs. Multi-year time series of ocean color data will be used to understand and predict the response of marine ecosystems to climate change.

We will continue the development of global land cover/use change data set based on Landsat and EOS instruments, at seasonal refresh rate. We will also continue to collect near-daily global measurements of the terrestrial biosphere from instruments on AM-1.

Short-Term Climate Events (Seasonal-to-Interannual Climate Variability)

ESE research focuses on observing, understanding, and predicting climate variations that occur on time scales of seasons to a few years. This effort is important because variations in the upper ocean circulation and ocean surface temperatures, ocean color, sea ice, atmospheric circulation including the hydrologic cycle, atmospheric turbidity, and land surface conditions such as soil moisture and snow cover are hypothesized to be mutually interactive and to generate significant variations of climate on seasonal-to-interannual time scales, both globally and in specific regions.

Airborne measurements made in the smoke clouds evolving from biomass burning in Brazil have yielded optical parameters that permit an improved assessment of the effects of smoke on Earth's radiation balance. These measurements were made in NASA's Smoke Clouds and Radiation experiment in Brazil (SCAR-B). Biomass burning of the Brazilian Cerrado (savanna) and tropical rain forest regions, contributes an estimated 25% of the global production of greenhouse gases and particulates. SCAR-B resulted in a significant reappraisal of estimates of global radiation forcing of aerosols from biomass burning (-0.8 W m-2 to -0.25 W m-2) and a factor of two reduction in uncertainty.
Theoretical analysis and aircraft measurements demonstrated that signals from Global Positioning System satellites reflected from the ocean may have numerous applications (e.g. altimetry, wind estimation, and ionospheric delay corrects for single frequency radar altimetry). Preliminary analysis of Space Shuttle data indicates that these reflected signals will be observable at orbital altitudes. With further confirmation and technical development, this represents a method of collecting information about the sea surface with substantially better temporal coverage and lower cost than other technologies.

In FY 1999, we will begin the second of a three-year sequence of instantaneous measurements of rainfall rates and monthly accumulations in the global tropics. This will be the first-ever measurement of global tropical rainfall. Current uncertainty in global tropical rainfall estimates is 50 percent; TRMM data will reduce this uncertainty to 10 percent, an 80 percent improvement.

We will provide 25 km resolution wind and direction measurements over at least 90 percent of the ice-free global oceans every two days. This represents a resolution increase of a factor of two, and a 15 percent increase in coverage over previous measurements.

In FY 2000, efforts will focus on the development/improvement of methods to couple state-of-art land surface and sea ice models to a global coupled ocean-atmosphere model and use this to predict the regional climatic consequences of El Niño or La Niña occurrence in the tropical Pacific. The ultimate goal is to develop a capability to significantly improve the prediction of seasonal-to-interannual climate variations and their regional climate consequences. The main focus is on North America. Measurements of the production and radiative properties of aerosols produced by biomass burning in Africa will be made as part of an international field experiment, the Southern African Regional Science Initiative-2000 (SAFARI-2000). The information obtained from this mission will assist in the interpretation of aerosol measurements made by instruments on NASA's EOS-AM spacecraft being launched in 1999. It is estimated that biomass burning in Africa contributes about one half of the global atmospheric aerosols.

The launch of NASA-CNES Jason-1 satellite mission will occur in FY 2000. This follow-on to TOPEX/Poseidon aims to achieve a factor of 4 improvement in accuracy in measuring ocean basin-scale sea level variability. This capability is one order of magnitude better than that specified for TOPEX/Poseidon.

Long-Term Climate System Variability

NASA contributes to broader national and international efforts to understand the causes and impacts of long-term (decades-to-centuries) variations in the climate system. Long-term climate variability encompasses changes of regional-to-global scale climate, both natural and human-induced, that occur over periods longer than a few years.

The Earth's weather and climate are driven by the transport of energy from the equator to the poles. Clouds modify the radiation budget of the earth at all latitudes, however, they can only form in the Arctic when breaks in the ice allow increased humidity and when pollution from lower latitudes provide nuclei on which to form. The NASA Arctic Cloud Experiment, performed in concert with surface observations provided through close coordination with the NSF sponsored Surface Heat Budget of the Arctic Ocean (SHEBA) project and the DOE sponsored Atmospheric Radiation Measurement (ARM) project, has provided detailed measurements of these subtle yet climatologically important processes. Results will also be used for the development and test of remote sensing algorithms for the EOS-AM1 MODIS instrument.

An ongoing project addressing the mass balance of the Greenland ice sheet by coordinated analysis of satellite, airborne, and *in situ* measurements indicates a warming trend since 1978. Increases can be found in the area of summer melting at lower elevations, but a more confused picture at higher elevations, with some areas thickening and some thinning. Results from repeated airborne laser surveys in 1998 and 1999, after a 5-year time interval, should help to clarify this picture.

There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like the El Niño events. In FY 1999, through the AM-1 instruments, we will begin conducting daily observations of cloud properties such as extent, height, optical thickness, and particle size. We will map aerosol formation, distribution and sinks over the land and oceans. In addition, we will achieve a substantial reduction in the uncertainty in components of the Earth's radiation balance (e.g. improved angular models leading to an estimated error reduction in regional-scale monthly-average net radiation of about 50%).

Efforts in FY 2000 include analysis of the CERES measurements to achieve a further reduction in the uncertainty in the determination of top-of-the-atmosphere radiative fluxes through the integration of measurements provided by the CERES instruments on TRMM and EOS AM-1.

The first detailed estimates of thickening/thinning rates for all the major ice-drainage basins of the Greenland ice sheet, derived from repeated airborne laser-altimetry surveys will be published. These measurements also represent a baseline data set for comparison with early measurements by the Geoscience Laser Altimeter System (GLAS), to be launched in July 2001. The airborne project for mapping of layers within the Greenland ice sheet to decipher the impact of past climate variation on polar regions will be initiated.

Natural Hazards

The long-standing Earth science research program in fundamental solid Earth science explored issues such as tectonic motions, earthquakes, and volcanic eruptions. Results of this, and other relevant projects are developed and applied to the mitigation and management of natural disasters, working together with practitioners at the international, federal, state and local levels.

Through the development of technologies designed to observe and understand the Earth, the ESE possesses an inventory of tools which can be developed and applied to understanding natural hazards, characterizing natural disasters, and monitoring conditions that may lead to such events.

In FY 1998, space-borne radar demonstrated the ability to monitor the surface deformation of a volcano from space. The volcano, Fernandia, in the Galapagos Islands, showed almost a meter of uplift on one of its flanks, evidence of subsurface movement of magma. This is an important element needed to provide warnings of eruptions.

In addition, a space-based method for monitoring volcanic gases for the volcano Popocateptyl in Mexico using the Earth TOMS during experiments in the low orbit mission phase was demonstrated. A 50% improvement in sensitivity monitoring gases was demonstrated in this orbit, making it possible to detect very small amounts of sulfur dioxide, which will aid in the development of an eruption warning system.

NASA's space geodetic measurement systems continued to improve to supply a mission-critical reference frame for satellites measuring global sea level change, ice sheet volume, and crustal motion. One system, very long baseline interferometry (VLBI), showed that it could also contribute to climate studies by detecting El Niño-related atmospheric influences on the Earth's speed of rotation.

In FY 1999, the NASA radar, flown in SIR-C, will be used by the DoD to create the first digital topographic map of 80 percent of the Earth's land surface. No ESE funds will be used for this mission known as the Shuttle Radar Topography Mission (SRTM), In addition, we will use GPS array in Southern California to monitor crustal deformation on a daily basis with centimeter precision and initiate installation of the next 100 stations. With GPS receivers in low earth orbit, we will test improved algorithms for sounding the atmosphere with the occulted GPS signal.

Research in FY 2000 will continue to develop models to use time-varying gravity observations, for the first time from space (in conjunction with the GRACE Mission) to estimate water storage changes to provide data to hydrologists on water mass expansion, flood impacts and climate variations. Demonstration of the utility of space-borne data for improved, faster and less costly flood plain mapping, an effort with Federal Emergency Management Agency will occur in FY 2000. We will use Southern California GPS array data to understand the connection between crustal movements and seismic risk to provide measures of earthquake vulnerability for disaster mitigation. An automatic volcano cloud/ash detection algorithm employing EOS data sets for use by the FAA will be developed. We will obtain, process and distribute imagery of current flooding for broad use in flood damage assessment and assessment of accuracy of flood plain maps comparing current flood insurance maps..

Atmospheric Ozone

NASA maintains an extensive research project related to atmospheric ozone in order to provide high quality scientific data on both the troposphere and stratosphere to the scientific community and to policy-makers who use such information in setting environmental policy.

In FY 1998, measurements of surface concentrations of chlorofluorocarbons (CFCs) and their replacements, halons, and other chemicals regulated under the Montreal Protocol and its Amendments showed a decreasing burden of regulated ozone destroying chemicals, and increasing abundance of replacement compounds less destructive to ozone in the lower atmosphere. These results confirm the efficacy of the Protocol which, if adhered to by the world's nations, will lead to recovery of the ozone layer sometime in the coming century. Satellite data have shown that the growth rate in the concentrations of the halogen-containing species formed in the stratosphere from the breakdown of CFCs and halons has begun to decrease, and continued observations should show stratospheric chlorine reaching its peak near the turn of the century.

Analysis of data made from a combined aircraft/balloon campaign based in Fairbanks, Alaska provided unprecedented detail about the annual decrease in summertime ozone levels in the high latitude northern stratosphere. These measurements showed that the - net ozone decrease in these regions near the summer solstice reached -16% per month. These data are proving very useful in the critical testing of the computational models used to simulate the ozone distribution in the current and future stratosphere.

Detailed study of measurements made as part of two tropospheric aircraft experiments and new photochemical model results have provided clear confirmation of the predominant role of in situ photochemistry (especially that associated with oxides of nitrogen) as the source of most ozone in the free troposphere. The role of downward transport of ozone from the stratosphere into the troposphere has been much better understood, including its seasonal and latitudinal contribution to tropospheric ozone amounts. For the first time extensive measurements of the important OH molecule in the lower troposphere have been reported together with extensive measurements on the processes that produce and destroy it, allowing for quantitative tests of ideas about its formation and destruction at these levels. Major new insights have also been gained on sulfur chemistry through the first measurements of several major sulfur compounds in the free troposphere. The formation of new sulfate particles has been observed in the remote troposphere for the first time shed new light on the way in which atmospheric pollutants are oxidized into radiatively important aerosols.

Trend studies of ozone distributions carried out over the past ~ 20 years using ground-, balloon-, and space-based observations have shown excellent agreement on loss rates of ozone in the upper stratosphere, which are consistent with computational models. Improved estimates of ozone loss in the difficult-to-measure lower stratosphere have been developed through refinements to the balloon-borne ozonesonde and satellite databases. Approximate downward trends in the 1980-1996 time frame are between 7.5% per decade at 15 km and 40 km and 2.5% per decade at 30 km.

Model calculations suggest important coupling between climate change and ozone depletion. Computer model calculations carried out for an atmosphere with increasing carbon dioxide amounts suggest that there can be complex interactions between climate and chemistry that could lead to enhanced ozone depletion in the Arctic. If the polar vortex were to become more persistent, as the model calculations suggest, there could be an increased chance for springtime ozone depletion in the northern hemisphere.

A continuing priority area will be the development of data sets suitable for long-term study of the evolution of atmospheric composition. A 20-year data set for total ozone will be constructed using data from the TOMS and SBUV/2 series of instruments. Long-term data sets for other TOMS products (surface UV flux, tropospheric aerosol distribution, tropical tropospheric ozone column) will also be constructed from TOMS data. A revised long-term data set for the vertical profile of ozone and aerosols will be obtained from the SAGE II instrument covering the first 14 years of its operation (1984-1998). Long-term data on the distributions of a variety of ozone-affecting trace chemicals in the stratosphere and upper troposphere, as well as of the solar ultraviolet radiation responsible for driving atmospheric photochemistry, will be provided by the Upper Atmosphere Research Satellite, which is now in its eighth year of operation.

The first initiation of the full Southern Hemisphere Additional Ozonesonde network to obtain the first ever climatology of upper tropospheric ozone in the tropics will be completed. This will involve the coordination of measurements made by a number of nations in the tropics and southern subtropics, and assembly into a database that can be easily used by the atmospheric science community.

The second Pacific Exploratory Mission in the tropics, PEM-Tropics-B, a focused airborne campaign (with an associated ground component), will be carried out in FY 1999 in order to further our knowledge of the distribution of ozone in the troposphere over the tropical Pacific. The detailed measurements of ozone and its sources provided by this mission, will provide additional seasonal and temporal information from that obtained during the first PEM-Tropics mission, and will make use of an improved in situ sampling payload. Analysis and interpretation of data will be carried out in FY 2000, while further improvements to the payload will be made to allow for an improved instrument complement to be used in another Pacific-based tropospheric chemistry mission planned for 2001.

We will continue to monitor and assess the impact of the Montreal Protocol and the Framework Convention on Climate Change with globally-distributed measurements of the surface level concentrations of long-lived industrially-produced trace gases and other biogenically-produced gases such as methane and nitrous oxide.

In addition, we will complete acquisition of first ever-global climatology of vertical profiles of carbon monoxide (CO) to improve knowledge of its surface sources, photochemical destruction, and how it is transported by tropospheric wind systems (based on MOPITT data from AM-1). Detailed validation of the MOPITT data product will be carried out with a variety of surface- and airborne-based in situ sampling, as well as ground-based optical remote sensing instruments.

Efforts in FY 2000 will implement the SAGE III Ozone Loss and Validation Experiment (SOLVE). Measurements will be made during the timeframe of October 1999 - March 2000 in the Arctic and high-latitude region in winter using the NASA DC-8 and ER-2 aircraft, as well as balloon platforms. The mission will also acquire correlative data needed to validate the SAGE III satellite measurements that will be used to quantitatively assess high-latitude ozone loss.

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Applications, Education and Outreach

The goal of the Earth Science Applications Research Program (ESARP) is to enable the productive use of ESE science and technology in the public and private sectors in response to user needs. To achieve the goal, the ESARP works with partners to extend Earth Science results, data and technology to a broad range of users. In FY 1998, ESARP competitively selected twelve Type 3 Earth Science Information Partners (ESIPs) out of 65 proposals and initiated implementation of the Cooperative Agreements for a project duration of 5 years. The ESIPs will be assisting to establish the EOSDIS Prototype Federation, and will also begin extending ESE science results, data and technology to the user community for routine decision-making. During FY 1998, the results consisted of the formal establishment of the Federation including developing a Federation Experiment Design Process, establishing a process of governance, implementing key governing committees, developing a secretariat, and formulating an evaluation design for the Federation in order to be able compare the coordinated Federation results in the future against the current EOSDIS design. In FY 1999, the Type 3 ESIPs will focus on applications development and interactions with the potential broader user community. Examples of partner activities include NBC Channel 4 in Washington, D.C. (weather and news) which is developing (system specification completed) an integrated News and Weather Visualization System for use within NBC owned and operated television stations. The system is based on using public and private remotely sensed data that would be used to generate products that can be used on-air. Another example is the New Mexico Earth Data Analysis Center (EDAC) which is working with state, regional and local problems. To date, they have worked with the New Mexico Land Office and Middle Rio Grande Council of Governments to develop baseline GIS databases and remote sensing applications for land economics and regional hydrology, and have developed a multimedia image sampler to introduce the broader user community to the types of data available for operation and commercial applications. A third partner, Reading Information Technology, Inc. is working to use remotely sensing data as part of a computerized decision support system to assist in determining sea conditions that would increase shipping cost and determine “optimized” ship routing. To-date, they have established the research partnership with Canadian Steamship Lines (CSL) and have successfully established GIS software on both ship and shore including the vessels’ GPS navigation. Future work is designed to create a system which automatically downloads the remotely sensed data into the software and provides a the means to deliver any need course or speed deviation to the vessel’s captain without human intervention. Another partner, the Bay Area Shared Information Consortium (BASIC) is working with the San Francisco Bay Area Governments and the wine industry to develop a multi-use, data sharing information system. To-date, they have worked with the

City of San Jose, Santa Clara Basin Watershed Management to understand their data needs and initiate development of application in watershed management, nitrate filtration, and water conservation.

In addition, ESE participated in over 30 partnerships with public and private user organizations to apply ESE science results, technology, data and expertise to routine decision-making such as developing biweekly "Green Reports" with the University of Kansas for assessing crop/vegetation condition, growth progress and change. These reports are distributed to 6,000 subscribers including farmers, agribusiness's, brokers and state and local government agencies.

In FY 1999, ESARP selected nine proposals which have been integrated into seven Regional Earth science Applications Centers (RESACs) designed to apply remote sensing and related technologies to problems of regional significance and conduct region specific assessments. The RESACs are addressing problems such as forest growth and health, precision agriculture, land cover and land use mapping and inventory, water resources management, rangeland quality assessment, fire hazard management, integrated watershed and coastal management, assessment of long-term agricultural productivity and sustainability. The outcome of the RESACs will be an enhanced knowledge of potential regional consequences of climate change and variability by regional stakeholders such as state and local governments and private industry. This knowledge will lead to practical advances in the management of regional resources. These advances will be accomplished through regional applications research projects resulting in improved inventories of forest growth, more accurate mapping of land use and land cover, improved assessments of rangeland quality and long-term agricultural productivity, integrated regional management of hydrologic and coastal resources, and reduced risk of loss due to fire resulting in millions of dollars of savings to society. At least one RESAC will become self-sustaining and at least 3 advanced applications and remote sensing products will become operationally used.

In addition, ESARP will initiate jointly with the USDA: (1) at least 8 new projects in the areas of vegetation mapping and monitoring, risk and damage assessment; and resource management and precision agriculture; and (2) 2 pilot projects leveraging the existing successful Land Grant and Space Grant networks into a cooperative NASA ESE/USDA Cooperative Extension Service Strategic Alliance in Geospatial Information Technology (i.e., remote sensing, GIS, GPS). Both of these activities will extend ESE's science results and push the existing applications science envelope forward in partnership with USDA. The Alliance will use remote sensing, GIS, GPS and other geospatial technologies to improve the benefits of traditional university extension activities for the Nation's farmers. The outcome will result in the development and validation of at least two new data products for routine decision-making by user organizations in the area of improved knowledge of capability and suitability of agricultural lands and increasingly efficient site specific agricultural techniques. The solicitation for cooperative Applications Research projects with state and local governments will also be completed and released.

In FY 2000, NASA contributions to the first USGCRP National Assessment of the Potential Consequences of Climate Variability and Change will be completed, with a report to Congress planned for January 2000. These will include production of the climate scenario information, support of the National Synthesis, several of the U. S. regional analyses, and supporting research for several U. S. studies. We will conduct the first regional international assessment in South Africa. This assessment will quantify the effects of climate variability and management practices on the environment. In addition, NASA will sponsor two regional assessment studies of environmental variations and natural resources vulnerability.

In FY 2000, ESARP will initiate at least 7 cooperative agreement with state and local governments in areas such as land use planning, land capability analysis, critical areas management, and water resources management resulting from the solicitation. These cooperative agreements will result in improved decision support systems in areas of priority needs defined by state and local governments including: land use and land cover inventory; land capability/suitability analysis; critical areas management; water resources management; forest inventory; site and route selection; and emergency preparedness. At least 2 new satellite remote sensing based applications will be developed in these applications areas as a result of these agreements.

In addition, based on the successful implementation of the pilot projects, the cooperative NASA/ESE USDA Cooperative Extension Strategic Alliance in Geospatial Information Technology will be expanded to at least an additional 5 states.

EOS science

In FY 1998, 52 new graduate student research grants (5% over goal) were awarded EOS Science Fellowship grants. In FY 1999, we will award 50 new graduate student research grants and 20 early career grants in Earth science. In FY 2000, we will award 50 new graduate student research grants and we will continue the 20 new U. S. early career grants in research/education in Earth science.

We will continue funding the original EOS interdisciplinary teams through FY 2000 and those selected with the NRAs in FY 1996 through FY 1999. Beginning in FY 2000 we will conduct a NRA for a new group of EOS Interdisciplinary scientist to fit with the new way of doing EOS missions.

Mission science teams and guest investigators

The mission science team/guest investigators funding provides for analyzing data from the UARS, TOPEX, Earth Radiation Budget Satellite (ERBS) and other spaceborne instruments such as Solar Backscatter Ultraviolet (SBUV/2), TOMS, and TRMM. The exploitation of UARS data still involves more than 100 investigators from the United States and many other countries, notably Canada, the United Kingdom, and France. Key TOMS and SBUV/2 participants include NOAA, Russia and Japan. Key ERBS users include a diverse set of institutions including NOAA (NOAA manifested Earth Radiation Budget Experiment (ERBE) sensors on NOAA-9 and -10 in the 1980's), GSFC, LaRC, the State University of New York, Oregon State University, and the Scripps Institution of Oceanography. The TOPEX users include France (shared in development of the mission), Japan, Australia, the United Kingdom, the Netherlands, Germany, Norway, and South Africa as well as JPL, GSFC, Columbia University, the University of Hawaii, the University of Texas, the University of Colorado, Oregon State University, Ohio State University, and the Massachusetts Institute of Technology. SeaStar/SeaWIFS principal users include GSFC, the European community, Japan, Canada, and Australia and universities in Florida, Washington, California, Texas, Maryland, and Rhode Island. At present, the largest demand for ocean color data arises from the Joint Global Ocean Flux Study (JGOFS), an international program under the auspices of the Scientific Committee for Oceanographic Research (SCOR) and the International Geosphere-Biosphere Program (IGBP). NSCAT investigators include scientists from JPL, NOAA, and Japan (manifested the NSCAT for flight on their ADEOS-1 spacecraft), and universities in New York, Washington, Oregon, and Florida. TRMM is a joint mission with Japan to measure tropical precipitation from a low inclination orbit. Participants in the analysis of SIR-C/X-SAR data, in addition to JPL,

represent nations in almost every continent including Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

Airborne science and applications

In FY 1998, twelve major campaigns were flown, over 1100 flight hours. The campaigns produced science data for rainfall, land-cover/land-use and atmospheric chemistry. Six major campaigns are scheduled for 1999, over 1300 flight hours. The core NASA Earth science aircraft fleet is fully subscribed, therefore lease, or other acquisition method, will be used to fulfill the requirements which cannot be met by the core fleet. The campaigns will return scientific data on tropical rainfall, tropical land cover, arctic ice, Pacific atmospheric chemistry, as well as land-cover/land-use, soil moisture and salinity.

Uncrewed Aerial Vehicles (UAVs)

The Uncrewed Aerial Vehicle (UAV) science project will augment the Earth science airborne project. Initially it will make i*n situ* and remote sensing measurements focused on atmospheric sciences. These UAVs will stay over a target for extended periods to measure detailed temporal changes, provide unique views of cloud structures and provide calibration and verification of Earth science satellite instrumentation.

Initial work in the UAV science was to develop and test a payload of instruments suitable for study of the radiation field in the upper troposphere and lower stratosphere as well as the relationship between atmospheric physical and chemical parameters and the radiation field. The centerpiece of this payload is a newly-constructed high resolution infrared and far infrared radiometer. The radiometer has been tested on the ER-2 and has been flown on the ER-2 together with several other instruments making measurements of atmospheric physical and chemical properties in order to provide enough data to test the retrieval algorithms used to interpret data from the radiometer. Both series of test flights were carried out from the Dryden Flight Research Center in California. In FY 1999 or early FY 2000, the plan is to fly the radiometer and a small number of other instruments on a UAV. The UAV must have sufficient flight heritage and instrument modifications will be necessary to mate with the selected UAV. For FY 2000 and beyond, a NRA will be issued soliciting concepts for UAV missions supporting the science and applications goals of the ESE.

Advanced geostationary studies

The Advanced Geosynchronous Study (AGS) effort has made significant progress in evaluating various new imaging, sounding, and lightning mapper instrument concept designs and technologies that could be applied to using geosynchronous orbit as a cost-effective vantage point for supporting Earth science research objectives as well as NOAA observational requirements. The study effort has also investigated technologies and concepts for advanced geosynchronous spacecraft and associated ground data processing and distribution techniques required to support the advanced instrumentation. All activities were closely coordinated between NASA and NOAA.

Commercial remote sensing

The goal of the Commercial Remote Sensing Program (CRSP) is to accelerate the development of a preeminent U.S. remote sensing industry and link Earth Science Enterprise scientists with the commercial remote sensing industry to develop mutually beneficial partnerships. To achieve this goal, the CRSP implements a variety of partnership programs that enable joint development of technology and applications with private companies, agencies, and educational centers. In FY 1998, the Commercial Remote Sensing Program (CRSP) sponsored over 25 joint projects with commercial firms in value added remote sensing product development. Approximately one third of these have begun new product development activities, and of the remainder, 10 trademark products have been introduced to the market. These companies report approximately $2 million in cumulative gross revenues and $20 million in capital investments in their companies which they attribute to their partnership with NASA. We established over 30 new agreements with private industry including: ESE Scientific Data Buy completed 10 phase 1 projects which resulted five phase 2 awards in September, 1998, negotiating 5 agreements for the Earth Observations Commercial Applications Program (EOCAP) SAR Data Initiative and 10 agreements for the EOCAP Hyperspectral Initiative. The Scientific Data Buy (SDB) is a pilot program developed to purchase remote sensing data from the private sector. This program is designed to advance Earth science research utilizing commercial data sources and to test a new way of acquiring science quality data. The EOCAP SAR Initiative seeks to determine the utility of advanced SAR applications. This program will also define commercially viable markets that radar technologies can address. The EOCAP Hyperspectral Initiative is designed to define the technology gaps that prohibit or impede the use of hyperspectral data in the U.S. industry and recommend solutions for filling those gaps. The final goal of this program is to have a sustainable and reliable commercial provider of spaceborne hyperspectral data.

In addition, the CRSP has extended their Affiliated Research Program (ARC) from four universities to nine. This allows CRSP to work with over 60 companies per year. Through short, well defined demonstration projects, these companies are examining the utility of remote sensing and geospatial technologies in providing solutions for their commercial customers. The Federal government's role in these activities is to perform fundamental research, advanced technology and applications development, validation of data and application performance to enable better management of Earth resources. Another outcome of these efforts is the exposure of graduate students to real world challenges in their areas of remote sensing expertise better preparing them to enter the workforce.

In FY 1999, Commercial Remote Sensing will establish at least 75 commercial partnerships in value added remote sensing product development, an increase from 37 in FY 1997 and 70 in FY 1998. This will result in further penetration into markets that rely on geo-spatial information in the management of earth resources. In addition, we will establish at least 20 agreements with industry in support of other federal agency needs (e.g., Department of Transportation (DOT), U. S. Department of Agriculture (USDA)). For example, remote sensing technologies and their role in precision farming will be investigated in a joint USDA and NASA initiative beginning in the year 2000. The application of remote sensing technologies improve the yield and reduce the cost of agricultural production. Specifically these projects will examine the use of remote sensing and geo-spatial technologies to assess soil variability and variable rate applications of seeds, nutrients, pesticides and herbicides to a variety of crops. With the DOT, remote sensing technologies are also being applied to the planning of transportation corridors and the analysis of traffic flow and infrastructure development. The state level departments of transportation will be enlisted to help validate these technologies. In FY 2000, the CRSP will focus EOCAP joint commercial applications research to develop 20 new-market commercial products. These products will provide the basis for commercial services to continue to support the ongoing geo-spatial needs of the Agricultural and Transportation agencies and the respective markets they represent.

Three commercial sources of science data (from data buy) for global change research and applications will be established. The science data will be made available to Earth science researchers for their investigations under terms consistent with the negotiated data licensing agreements with the commercial data providers. Two new validated commercial information products will be developed as a result of verification and validation partnerships with industry to increase customer confidence and product understanding. These products will provide a validated baseline of the new commercial remote sensing satellite and airborne offerings that will be available in the near future.

BASIS OF FY 2000 FUNDING REQUIREMENT

OPERATIONS, DATA RETRIEVAL AND STORAGE

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Mission operations	47,000	56,300	54,600
(Upper Atmosphere Research Satellite)	(4,800)	(8,200)	(6,700)
(Total Ozone Mapping Spectrometer)	(2,700)	(2,700)	(3,000)
(Ocean Topography Experiment)	(10,700)	(11,000)	(11,100)
(Tropical Rainfall Measuring Mission)	(10,600)	(10,900)	(11,000)
(Satellite Laser Ranging)	(5,700)	(5,700)	(5,000)
(Earth Science)	(12,500)	(17,800)	(17,800)
High Performance Computing And Communications- Earth And Space Sciences	18,300	14,500	21,900
Information systems	4,300	6,100	6,400
Total	69,600	76,900	82,900

PROGRAM GOALS

Operations, Data Retrieval and Storage (ODRS) provides the data and data products from EOS precursor missions, including the UARS, TOPEX, TOMS, NSCAT and TRMM, required to understand the total Earth system and the effects of humans on the global environment. The goals of the NASA High Performance Computing and Communications (HPCC) project are to accelerate the development, application and transfer of high performance computing technologies to meet the engineering and science needs of the U. S. aeronautics, Earth science, and space science communities and to accelerate the implementation of a national information infrastructure.

STRATEGY FOR ACHIEVING GOALS

This project supports the observations and data management portion of Earth science activities. The project will achieve its goals through the following: mission operations, high performance computing and communications, and information systems. The data and data products from this project have or will migrate to the EOSDIS.

Mission Operations

The objectives of the mission operations program are to acquire, process, and archive long-term data sets and validated data products. These data sets support global climate change research in atmospheric ozone and trace chemical species, the Earth's radiation budget, aerosols, sea ice, land surface properties, and ocean circulation and biology. Funding provides for operating spacecraft such as UARS, TOPEX, ERBS, TOMS, TRMM, and processing of acquired data. Key users of UARS data include NOAA, the Naval Research Laboratory, GSFC, JPL, Canada, the United Kingdom, and a number of universities including the University of Michigan, the Georgia Institute of Technology, the University of Washington, the State University of New York, and the University of Colorado. Key TOMS proponents include NOAA, Russia (manifested a TOMS on their Meteor 3 satellite launched in 1991), Japan (manifested a TOMS on their ADEOS satellite launched in 1996). Key ERBS users are a diverse set of institutions including NOAA (manifested ERBE sensors on NOAA-9 and -10 launched in the 1980's), GSFC, LaRC, the State University of New York, Oregon State University, and the Scripps Institution of Oceanography.

Key participants involved in the Alaska SAR Facility (ASF) include the European Space Agency (ERS-1 and -2), Japan (JERS-1), Canada (RADARSAT), GSFC, JPL, and the University of Alaska which hosts the ASF. Participants in the analysis of SIR-C/X-SAR data, in addition to JPL, represent nations on almost every continent and include: Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

The Satellite Laser Ranging (SLR) System is NASA's contribution to a world-wide laser ranging network. In additional to providing extremely precise tracking for a number of spacecraft (including TOPEX and a host of international missions), the SLR network makes significant contributions to Earth science (such as precise measurements of the gravity field and the station's vertical position with respect to the Earth's center of mass).

The Optical Transient Detector (OTD) instrument has numerous customers for data including NASA, NOAA, USAF, Massachusetts Institute of Technology, Texas A&M, University of California at Los Angeles, Colorado State, and international requests for data from Chile; German Aerospace Center (DLR); University of Frankfurt, Germany; the Swiss Institute of Atmospheric Physics; South Africa; Mexico; Hungary; Tel Aviv University and Haifa University, Israel; the United Kingdom Meteorological Office; France; Potsdam Institute for Climate Impact Research, Germany; and China.

High Performance Computing and Communications (HPCC) - Earth and Space Sciences

The NASA HPCC program consists of five discipline-related integrated projects. These projects are Computational Aerosciences (CAS), managed by the Office of Aero-Space Technology; Earth and Space Sciences (ESS), managed by the Office of Earth science; Remote Exploration and Experimentation (REE), managed by the Office of Space Science, National Research and Education Network (NREN), managed by the Office of Aero-Space Technology, and Learning Technologies (LT). The LT project focuses on providing the technology base and applications to accelerate the implementation of the national information infrastructure and to communicate and distribute science and engineering materials to the education community.

The implementation of the NASA HPCC program is mainly through coordinated activities at NASA field centers. The ESS project, led by GSFC, will work in close partnership with industry, academia and government. The project used the NASA research announcement process to select ten principal investigator teams and twenty-one NASA/NSF sponsored Grand Challenge investigations and to implement them on advanced parallel computers. The LT project uses remote internet technologies developed by NASA and other federally funded agencies to expand the application outreach of its programs to traditionally unserved communities. The Internet is used as the primary means of providing access to and distribution of science and engineering data.

Information Systems

The Earth science information system project has been structured to provide a balanced system of high performance computers, mass storage systems, workstations, and appropriate network connectivity between researchers and components of the system. A major portion of the project funding supports operation of a supercomputing center (the NASA Center for Computational Sciences) at GSFC. A full range of computational services are provided to a community of approximately 1,400 users representing all disciplines of Earth and space sciences. Users of the supercomputer complex select representatives to an advisory committee who are integrally involved in strategic planning for the evolution of the complex. They provide feedback on user satisfaction with services provided and help establish priorities for service and capacity upgrades. Offsite NASA-sponsored users comprise 25% of the total. The project monitors and participates in advanced technology projects, such as the HPCC program and National Science Foundation's gigabit testbed programs. Project elements at GSFC and JPL are focused on providing early access to emerging technologies for the Earth and space science communities. The early access to new technology provides the project with the opportunity to influence vendors and system developers on issues unique to the Earth and space science researchers such as data intensive computation and algorithm development. Early access also prepares a subset of the research community to make changes in research methodology to exploit the new technologies and to champion promising technologies to their colleagues and peers.

SCHEDULE AND OUTPUTS

OPERATIONAL SPACECRAFT/INSTRUMENTS

Common to all missions:	
Archive 95% of planned data acquisition	The primary criteria for success of an operational spacecraft is to obtain 95% of the planned data acquisition.
UARS (launched September 1991) continuing operations	The spacecraft launched in September 1991 with an expected five-year mission life. It has gone well beyond the expected mission life providing data to support improvements monitoring the processes that control upper atmospheric structure and variability, the response of the upper atmosphere to natural and human-induced changes, and the role of the upper atmosphere in climate variability.

TOPEX/Poseidon (launched August 1992) continuing operations	The spacecraft launched in August 1992 with an expected three-year mission life. The extended mission was defined to be three additional years. It is now in the final year of this extended mission life.
ERBS/ERBE/SAGE II (launched Oct. 1984, December 1984 and September 1986) continuing operations	The ERBS spacecraft launched in October 1984. It has gone well beyond the expected mission life.
Alaska SAR Facility Missions: ERS-1 (launched 1991) JERS-1 (launched 1992) ERS-2 (launched 1995) RADARSAT (launched 1995) ADEOS (launched 1996)	The Alaska SAR Facility is a ground receiving station and data processing station with no "end of life" defined. It supports ERS-1, JERS-1, ERS-2, and RADARSAT. All of these are international missions. There are currently no unique metrics defined for ASF other than the common metric listed above.
OTD (launched 1995) continuing operations	This instrument was launched in 1995 as a six-month technology demonstration. It has far exceeded its designed mission life.
TOMS FM-3 (launched July 1996) continuing operations	The TOMS-EP spacecraft was launched in July 1996 with an expected five-year mission life. It is currently in its primary mission phase. The first global ozone image was produced and released September 13, 1996. Automated processing and distribution of science products began September 20, 1996 and Internet distribution started on October 7, 1996.
TRMM (Launched November 1997) continuing operations	The spacecraft launched in November 1997 with a three year mission life. All operations are nominal, except the CERES instrument is non-operational due to an anomaly with Data Acquisition Assembly Converter.
SeaStar / SeaWIFS / Ocean Color (Launched August 1997 continuing operations for data processing)	The spacecraft launched in August 1997. This is a data buy from Orbital and the operation of the spacecraft is an Orbital responsibility.

ACCOMPLISHMENTS AND PLANS

Data has been acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products for global and/or regional monitoring purposes from all operational spacecraft and instruments. The current emphasis on global modeling in support of policy decisions on such matters as the impact of deforestation, ozone depletion, and environmental quality worldwide has led to the acquisition and manipulation of unprecedented amounts of environmental data. The accompanying computational demand has led to a doubling of production computing capacity and quadrupling of mass storage capacity in the last two fiscal years. These added demands are being addressed in the agency's initiative to consolidate supercomputer-based information systems.

In the mission operations project, responsibility for assigned missions is assumed 30 days after launch. Data are acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products.

User requirements will be met in 1999 and 2000 by continuing operations of on-orbit spacecraft and instruments including the UARS, TOPEX, and ERBS missions; and continuing receipt of ERS-1, JERS-1, and RADARSAT data at the Alaska SAR Facility. In addition, OTD, SeaStar/SeaWIFS, TOMS and TRMM. The NSCAT instrument, while no longer operational, is still undergoing levels of data processing.

The TRMM transitioned to routine operations in 1998. Data processing for the SAGE III instrument will begin in 1999.

The Earth science information systems project will continue to provide a balanced computational environment for NASA science researchers primarily through facilities housed at GSFC and JPL. Partnerships with industry and other federal agencies will be used to assure the presence of the project's requirements in the strategic planning of new computational technologies. Recently initiated cooperative agreements will allow the development of supercomputer applications 10 times faster than today, providing the computational studies necessary to mesh with NASA's observational and theoretical projects.

BASIS OF FY 2000 FUNDING REQUIREMENT

GLOBAL OBSERVATIONS TO BENEFIT THE ENVIRONMENT (GLOBE)

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Global Observations To Benefit The Environment	5,000	5,000	5,000

PROGRAM GOALS

The goal of the Global Observations to Benefit the Environment (GLOBE) program is to link scientific discovery with the education process in the study of the Earth as an integrated system. The objective is to bring school children, teachers, and scientists together to: (1) enhance environmental awareness of individuals throughout the world; (2) contribute to scientific understanding of the Earth; and (3) help all students reach higher levels of achievement in science and mathematics.

STRATEGY FOR ACHIEVING GOALS

The GLOBE program is an interagency activity led by NOAA in which NASA has a key role. It involves students (kindergarten through twelfth grade or equivalent) in schools throughout the world, their teachers and the research community. Participating schools are making core sets of GLOBE measurements using GLOBE instruments and procedures under the guidance of GLOBE-trained teachers. The results from all over the world are reported into a central data processing facility. The students then receive feedback and use GLOBE educational materials to understand the compiled results and do their own analyses of the data.

In order to meet the first objective of increasing international environmental awareness, the program has been designed to be international in scope, involving students, educators and researchers from all over the world. By using the Internet to link the schools together, a sharing of discoveries and analysis is encouraged that should result in awareness beyond just the local community.

The second objective to contribute to the scientific understanding of the Earth, is achievable due to the expansive data sets that result from long term, repeated measurements made in areas where data has in some cases been extrapolated in the past. To ensure the greatest possible accuracy of the data, international environmental scientists have been involved from the beginning of the program to select a set of significant scientific measurements that can be made by students and define the experimental procedures and data reporting protocols for each.

SCHEDULE AND OUTPUTS

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Revised	Plan
Number of Participating Schools	6,000	5,400	8,000	8,000	10,500

ACCOMPLISHMENTS AND PLANS

By the end of FY 1998, The GLOBE program continued its rapid growth across the United States, focusing on areas of special interest, including empowerment zones and rural areas. For teacher training, a compliment of train-the-trainer and franchise approaches was incorporated to meet the demand and resources which are applied from GLOBE's private sector partner. Schools participating in GLOBE increased to 5,400, a 26% increase from 4,300 in FY 1997. In addition, countries participating in GLOBE increased to 70, a 14% increase from 62 in FY 1997.

In FY 1999, GLOBE will conduct at least 300 workshops to train teachers in use of ESE education products. The number of schools participating in GLOBE will increase to 8,000, a 30% increase over FY 1998 and the number of participating countries will increase to 72, up from 70 in FY 1998.

During FY 2000, GLOBE will sponsor at least 300 workshops to train teachers of OES education products. The number of participating schools in GLOBE will increase from 8,000, in FY 1999, to 10,500. Also, the number of participating countries in GLOBE will increase from 72, in FY 1999, to 77.

BASIS OF FY 2000 FUNDING REQUIREMENT

LAUNCH SERVICES

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Launch services.....	39,400	4,200	---

PROGRAM GOALS

The goal of the launch services within the Earth science project is to provide the flight projects with cost-effective, on-time Expendable Launch Vehicle (ELV) launch services.

STRATEGY FOR ACHIEVING GOALS

The launch services budget includes funding through FY 1999 to support EOS AM-1 and Landsat-7 mission support needed to maintain the capability for Earth science missions. Beginning in FY 1999 the mission support is consolidated with Space Science mission support and budgeted in Human Space Flight.

SCHEDULE AND OUTPUTS

EOS AM-1 Plan: June 1998 Revised: July 1999	To be launched on an Atlas IIAS from Vandenberg AFB.
Landsat-7 Plan: December 1998 Revised: April 1999	To be launched on a Delta II from Vandenberg AFB.

ACCOMPLISHMENTS AND PLANS

Funding will continue in support of the EOS AM-1, Landsat-7 launches in 1999.

BASIS OF FY 2000 FUNDING REQUIREMENT

CONSTRUCTION OF FACILITIES

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Construction of Facilities	---	1,500	1,000

For additional detail, refer to the Mission Support, Construction of Facility section.